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COTTON STATES BRANCH

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ANOMIS EROSA HUBN. AS AN INSECT PEST OF COTTON

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Nature of injury and economic importance.—Writers have often stated that the larvae of the Abutilon moth are not very numerous upon the cotton plant. It is very possible that when they made their observations there was only a slight infestation by this species. During the three years that the writer has made detailed observations of this form it has been found that they are numerous. During a collecting trip in the fall of 1931, several hundred lepidoptera pupae were collected from a cotton field located near Gainesville. Around 50 per cent of the adults emerging from the pupae were *Alabama argillacea* and 50 per cent were *Anomis erosa*.

The larvae consume large quantities of leaf tissue, especially during the latter part of the larval instar. During the late stadia they consume the entire leaf and may completely defoliate the plant. A discussion concerning the economic importance of a leaf caterpillar upon cotton is rather difficult. This is true because numerous workers state that the defoliation of the plant causes a rapid maturing of the bolls and prevents injury by *Anthonomus grandis*. This the writer agrees with, in part. However, he does not believe that excessive defoliation is beneficial to a plant that is setting fruit. A partial reduction in leaf area may be beneficial.

Host plants.—Numerous plants of the Malvaceae have been found to be subject to attacks by this species. The following are damaged quite extensively by the larvae: flowering maple (*Abutilon striatum*), okra (*Hibiscus esculentus*), cotton rose (*Hisbiscus mutabilis*), roselle (*Hibiscus sabariffa*), Chinese mallow (*Hibiscus sinensis*), cotton (*Gossypium* spp.), swamp or rose mallow (*Hibiscus moscheutos*), bell pepper (*Pepperomia* spp.), and *Urena lobata*, *Abutilon avicenna* and *Malva rotundifolia*.

Life history and habits.—The okra caterpillar may be found in all stages throughout the year, in southern and central Florida. In the north-

ern and northwestern parts of the state the insect may hibernate as a pupa. Temperature experiments indicate that the pupal stage is the hibernating stage in all northern regions.

The adults are very rarely seen in the field. They conceal themselves on the under side of the leaves during the day, and come out at dusk and at night. The dehiscence of the adult usually takes place at night. Copulation may take place 24 hours after emergence. One pair of adults were observed *in coitu* some 18 hours after emergence. Numerous adults were discovered *in coitu* about 7–7:30 a.m. During the mating process the male and female face in opposite directions. The apical margins of the female's primaries overlap those of the male.

Length of time from emergence to oviposition varies. Some adults deposited eggs five days after dehiscence and continued ovipositing for 27 days. This causes a great overlapping of broods. Larvae from the first eggs deposited may pupate before the adults have ceased ovipositing.

The eggs are usually deposited during the night. The female seems to prefer the lower surface of the leaves for oviposition, but may deposit them upon the upper surface and at times along the stems. The eggs are attached firmly to the surface of the leaf. They are deposited singly and not in agglutinated masses. In order to secure eggs, the writer had to place the adults in groups of twenty or more. This prevented the securing of definite records upon the fecundity of the females.

Incubation results were obtained for 4382 eggs. The maximum length of time required was six days; the minimum was three days; and the average was 4.2 days. The young larvae usually emerge from the egg during the night. Just after eclosion they may feed upon the egg shell or upon the leaf.

The young larvae usually feed upon the lower surface of the leaves. The upper epidermis is not consumed. They are very active during the first three stadia. If they are disturbed they will drop readily by a silken thread. After stopping in mid-air, they may climb back up the thread of silk. The young caterpillars, feeding upon the lower surface of the leaves, are sometimes very hard to detect, as they are practically the same color as the leaf.

During larval life this species goes through five distinct stadia. Riley describes seven larval stages. The writer has never observed over five. The length of the larval instar averages 16.1 days. The maximum length of time spent in this instar was 22 days and the minimum was 13 days. The length of the larval stage will depend to a great extent on the season of the year in which the development is taking place.

When the larvae reach larval maturity they draw the leaf over them, with the aid of cephalic silk. They then spend one to two days in the prepupal stage, after which time they pass through the last larval ecdysis and become pupae. Just after pupation, the pupae are a bright green color, becoming darker in a few hours. They gradually turn a deep brown and some become almost black, before dehiscence of the imagines.

The length of the pupal stage averages 11.9 days. The maximum time spent in this stage was 15 days, and the minimum 8 days. The length of the pupal stage is undoubtedly affected by seasonal conditions.

Temperature studies.[1]—Fifteen male and female insects were subjected to Frigidaire temperatures. Some were subjected the day of dehiscence and others were held at laboratory conditions for two or three days and then subjected. The average length of life for all individuals used in the test was six days. This indicates that the imagine is not the hibernating stage of *Anomis erosa*.

Twenty-five larvae in the second and third stadia were used in this test. They were transferred from the laboratory to the Frigidaire and allowed to remain one to 25 days. Each day a larva was removed to laboratory conditions and hourly observations were made. Only one larva survived. This was the individual that was subjected only one day. The remaining 24 were dead upon removal. This indicates the inability of this species to pass the winter in the larval stage.

Twenty-five prepupa were used in a test to determine the effect of low temperature upon this stage. Only two individuals survived. These were one that was subjected for one day and one that was subjected for four days. The remaining 23 died in the Frigidaire.

Twenty-three pupae were subjected to a Frigidaire temperature of 7–9° Centigrade. They were allowed to remain from one to 23 days. Each day a pupa was removed to the laboratory and further observations made. Pupae, up to and including those subjected 19 days, emerged after being transferred to the laboratory. All pupae subjected 20 or more days died either in the subjection chamber or after removal to laboratory conditions. Of those individuals that emerged, the only effect upon the pupal stage was to increase the length of the stage the number of days that they were subjected. The emerging adults were not deformed and upon being placed in breeding jars they mated and the females deposited fertile eggs. The above results indicate that in the northern districts the species likely hibernates in the pupal stage.

Distribution.—In the United States *Anomis erosa* Hubn. is known to occur in 17 of the 48 states: Alabama, Florida, Georgia, Kansas, Louisiana, Maryland, Massachusetts, Mississippi, Missouri, New Jersey, New Mexico, New York, North Carolina, Ohio, South Carolina, Texas and Virginia. It has also been reported from the District of Columbia. The writer believes that this species is, at least, generally distributed all over the eastern and midwestern United States. It undoubtedly occurs in many states that have never reported it. Oklahoma, Arkansas, Tennessee, Kentucky, Illinois, Indiana, West Virginia, Pennsylvania, Connecticut, Vermont and New Hampshire probably have this pest. All are adjacent to states that have reported the presence of this species.

Anomis erosa Hubn., has been reported from various parts of the world: south of the United States it has been reported from Mexico, Colombia, Brazil, Peru, Argentina, Paraguay and practically all of the West Indian islands. Though it has not been reported from Honduras, Nicaragua, Panama and several of the South American states, it is probably generally distributed throughout Central and South America wherever its hosts occur. North of the United States it has been reported from Quebec, Canada.

[1] All temperature tests were conducted in a Frigidaire at a constant temperature of 7–9° Centigrade.

At various times it has been reported from districts in Africa. Several times these have been denied. A positive report was given from the Nyasaland Protectorage, and from Salisbury in South Africa.

The writer has received positive reports from Punjab and Allahobad, India. It is very likely a generally distributed species in this district. It has also been reported from Ceylon. Positive reports were obtained from South Indo China. The Official Entomologist of Japan reported that it had been collected at Taiwan (Formosa), Kiushu, Honshu and Ogassawaro. In Australia it has been reported as present in Queensland and New South Wales. It is very likely a generally distributed pest in Australia. *Anomis erosa* probably occurs on the Philippine Islands and in the Dutch East Indies, especially Sumatra, Borneo, Celebes, Java and New Guinea. It has been definitely reported from New Zealand. The writer is of the opinion that this species is very widely distributed. It probably occurs in numerous other countries, but is not economic enough to attract very much attention.

Parasitoids.—There are several parasitic enemies of this species. Probably one of the most common and efficient is a Hymenoptera that parasitizes the pupa. This is *Syntomosphyrum esurus* Riley. This species is also one of the most common pupal parasites of *Alabama argillacea*. Another hymenoptera that aids materially in the control of *erosa* is *Trichogramma pretiosa* Riley. It also parasitizes the eggs of *argillacea*. The writer has taken two diptera that attack this form. They are *Megoselia scalaris* L. and *Publiciphora* spp.

Predators.—There are several hemiptera that have been found preying upon the larvae and pupae of *Anomis erosa* Hubn. The writer collected the following: *Podisus maculiventris* Say, which is one of the most common of the predators; *Zelus bilobus* Fabr., which is a very common predator in Florida; *Dysdercus suturellus* Herrich-Schaffer, which is very efficient in this state; *Nezara viridula* Linn., the green soldier bug which is predacious on a number of insects. The larvae of a dipterous form was found to be a very efficient predator. This was *Allograpta obliqua* Say. There are numerous wasps that feed upon the larval stage of this species. The writer observed several species feeding upon them, but was unable to collect them.

NOTES ON LITTLE-KNOWN COTTON INSECTS

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Naturally, the most important cotton insects, particularly the boll weevil, have been studied most; and minor pests have been studied somewhat in proportion to their economic importance. There still re-

[1] The original observations recorded herein were made in 1934, with the assistance of G. M. Webb and K. H. Smith, temporary assistants.

Through the courtesy of Dr. Harold Morrison of the Division of Insect Identification, certain species of Coleoptera were determined by L. L. Buchanan, H. S. Barber and E.A. Chapin, and species of Lepidoptera by August Busck, F. H. Benjamin and Carl Heinrich.

main, however, a large number of species that frequent the cotton plant whose biological relations to the plant are little known or unknown. In fact, cotton insects continue to afford a most fruitful field for economic investigations.

The writer studied especially the feeding habits of many of the overlooked cotton insects in the last season at Tallulah, La., and found that some of these species were of considerable economic importance because they killed large numbers of leaf buds and squares. Although the damage from any one of these species was usually not very extensive, the collective damage by all the species concerned was sufficient to be important. The significant findings regarding the various species are briefly discussed in the following notes:

COLEOPTERA

Monocrepidius vespertinus (Fab.).—The wireworm of this elaterid is a well-known pest that bores into planted seeds and the roots of young cotton plants. The damage done by the adults, however, seems to have escaped notice. The bettles are very common every year, especially in July, on all parts of the cotton plant. They often feed in the bud cluster, killing some or all of the buds. On leaves they eat the lower skin and the parenchyma, leaving the upper epidermis. Their damage to the leaves of large plants is of no consequence, but small plants with only a few leaves are sometimes killed by them.

Trigonopeltastes delta (Forst.).—This scarabaeid does not appear in our economic literature. It ate holes in leaves and petioles early in September.

Pachybrachys confederatus Fall.—In July this chrysomelid beetle ate into squares, causing them to fall.

Bassareus clathratus (Melsh.).—This chrysomelid, overlooked as an economic species thus far, was common on young cotton from June 22 to July 12. It ate holes in young squares, killing them; gnawed holes in bracts and leaves; and especially chewed out pits for long distances along the main stems, causing the stems to turn brown and the plants to wither.

Colaspis brunnea (Fab.).—The adults of this chrysomelid, the grape colaspis, are known to eat the cotton plant voraciously, especially to gnaw the edges of bracts and to riddle bracts and leaves with holes. The beetles do more damage than has been reported, however, for they also ruin large numbers of squares. In squares about a quarter of an inch long the beetle eats a large hole and excavates the square, which falls within 24 hours. Even squares with only the bracts eaten turn brown and fall. On young plants the beetles eat leaf buds and small squares, blasting them, and often kill small plants by eating the leaves or by eating pits in the main stems and the petioles. Most of the damage is done in July.

Nodonota tristis (Oliv.).—This flea beetle, already known to occur, sometimes in large numbers, on leaves of plum, peach and other fruit trees, was very common in June on cotton plants, especially among the terminal buds, which it killed. It made small holes in the leaves and also ate along the edges in the manner of a caterpillar.

Ashmead (*1*) observed that this species gnawed into the epidermis of

bolls, thus exposing the tissue to the weather and causing them to drop.

Myochrous denticollis (Say).—This widely distributed chrysomelid beetle, which does serious damage to young corn plants, also destroys young buds of the cotton plant, eats the softer parts of squares and the tips of bracts, and kills young cotton plants by gnawing into the stems.

Systena elongata (Fab.).—This chrysomelid beetle feeds on all parts of the cotton plant, but is fortunately not abundant, and is not on record as an injurious species. It often eats into squares, causing them to fall, and blasts small squares in clusters of buds. It makes pits on stems, and skeletonizes bracts and leaves, gnawing off the upper epidermis and the parenchyma beneath. Small plants may be killed by the beetle.

Notoxus calcaratus Horn.—During the last of August this anthicid beetle fed on squares, which subsequently fell.

Compsus auricephalus (Say).—This conspicuous green curculionid ate the leaves of seedlings. A pair taken on cotton were *in coitu* on May 15, and on the next day 32 eggs were laid. These eggs were in a flat cluster on the upper side of a seed leaf in a sticky fluid, with the opposite half of the seed leaf folded over and concealing the cluster. Such arrangement has been noted by Pierce (*5*). The beetles lived until July 20 and 21, respectively, meanwhile feeding constantly on cotton leaves.

Conotrachelus erinaceus Lec.—From the middle of June into September this curculionid (new as a cotton insect) was common and generally distributed. It occurred usually in the bud clusters of the cotton plant, where it ate into the buds and killed them. It blasted many young squares and caused older squares to flare, turn yellow and drop. The beetle feeds also to some extent on stems and leaves and may kill small plants.

Conotrachelus anaglypticus (Say).—Larvae of this species infest cotton bolls, according to Brooks (*2*). In July and August we found the beetles feeding on squares, making them turn yellow and fall.

Centrinaspis picumnus Hbst.—During the last week of July this curculionid fed in the bud clusters of a small cotton plant and killed it.

Lepidoptera

Apatela longa Guen.—One caterpillar, taken on cotton, fed heavily on leaves and bracts, and gnawed into stems.

Heliothis virescens (Fab.).—Under the name of the tobacco budworm, this pest is well known. It has commonly been overlooked on cotton, however, doubtless owing to its close resemblance to the congeneric *H. obsoleta*, the boll worm; in fact, a close comparison is often necessary to distinguish one from the other. Distinguishing characters have been described and figured by Garman (*4*).

In the season of 1934 *virescens* was almost as common as *obsoleta*. It works in the same manner as the boll worm, but prefers squares to bolls, and eats leaves more freely. Probably much of the damage attributed to *obsoleta* is done by *virescens*.

The caterpillar eats a round hole into the side of a square and excavates the contents; then it may go to another square. Occasionally it pupates inside a square, but as a rule it goes to the ground, where it re-

mains from 11 to 14 days in July and August, and as many as 20 days in September. In the insectary, moths emerged constantly from July 19 to September 28.

Autographa brassicae (Riley).—The well-known cabbage looper is occasionally, but locally, a pest on cotton. It was common in Madison Parish, La., in 1934 for the first time since 1925, when it defoliated large areas of cotton. The looper rags the leaves of cotton plants in the manner of the leaf worm *Alabama argillacea* Hbn., and like that species pupates among the leaves. In 1925 the looper reduced the amount of foliage sufficiently in July to retard the growth and development of cotton plants, and destroyed immense numbers of squares.

Autographa oo Cram.—A few caterpillars of this species were found eating the leaves of cotton. One pupated on August 21, and the moth issued on August 30.

Anomis flava fimbriago Steph.—We raised two of the moths from cotton squares.

Hypsoropha hormos Hbn.—One larva of this noctuid (unrecorded as an economic species) was found on cotton on June 22. It fed on the leaves, spun a cocoon on June 25, and the moth emerged on July 7.

Cleora pampinaria Guen.—This omnivorous spanworm, destructive locally and sporadically to cranberry, is already on record as eating the flowers of cotton. Two of the caterpillars taken on cotton fed on the leaves. They buried themselves in the ground on July 2 and August 1, respectively, and became moths on July 14 and August 13.

Loxostege helvialis Walk.—This pyralid was found feeding on the leaves of cotton. The moth appeared on August 22 from a cocoon spun on August 11.

Sparganothis sulfureana Clem.—A caterpillar of this tortricid, previously found on wild cotton in southern Florida by C. F. Rainwater (unpublished notes), was found inside a small cotton square from Leland, Miss., on July 16. The inside of the square had been eaten out. The larva spun a cocoon among the buds of a plant on July 23, and the moth issued on July 30.

Sparganothis directana Walk.—On June 1 a caterpillar of this species, which has not been listed as an economic form, was taken inside a square. On June 15 it drew a leaf around itself and was a pupa on June 22. The moth emerged on July 2.

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AN UNDERGROUND ROOM FOR BREEDING PARASITES

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The parasite insectary at Presidio, Tex., with a breeding room located below the ground level, has proved so satisfactory that information concerning its construction and advantages is here given for the benefit of other workers.

Temperatures of 100 to 110° F in summer and of 20 to 25° F in winter are not infrequent at Presidio, and in this semiarid section the humidity is usually very low; so that when the insectary was built in 1932 it was decided to locate the breeding room in a basement to avoid the extreme fluctuations in temperature. The room was not originally intended for studies of insects under constant temperatures, but rather to provide more favorable conditions of temperature and humidity. When it later became possible to install equipment for regulating both of these factors throughout the year in the breeding room and for maintaining a cold-storage room, it was found that the below-ground location contributed materially to the reduction of operating costs.

The upper part of the insectary is of the usual frame construction, 12 by 32 feet, one end of which is screened with wire and the other half weather-boarded and lined with composition boards on walls and ceiling for insulation. The breeding and cold-storage rooms are beneath the enclosed part, opening independently from a small hallway at the foot of the steps. The basement walls are of 8-inch concrete, waterproofed with asphalt, and are entirely under ground except that two windows, just under the ceiling of the breeding room open into shallow outside pits. The windows are fitted with double sashes with air spaces between for insulation and are set in concrete so that they cannot be opened.

The cold-storage room has a floor space of 3 by $6\frac{1}{2}$ feet and a wall height of $6\frac{1}{2}$ feet. It is insulated with 4 inches of cork board and fitted with a standard cold-storage door. The breeding room proper is $7\frac{1}{2}$ by 11 feet by 7 feet high. Entrance to this is through a vestibule which serves as a safeguard to prevent the escape of undesirable insects. The door to this room is also insulated and fitted with felt gaskets. The walls and ceiling are covered with 1-inch cork board. Forced ventilation is provided through a grill in the ceiling.

The electrically driven refrigerating unit is located on the main floor, with independent automatic controls for the two rooms. It is of the direct expansion type using ammonia as a refrigerant, with a refrigerating capacity of one ton of ice per day. The refrigerating coils in each room are of the compressed type made of $1\frac{1}{4}$-inch pipe in continuous welded length and fastened to the side walls. The cold storage room has 125 linear feet of this coil with a heat-absorbing area of approximately 54.3 square feet, designed to maintain the temperature as low as 32° F, with a maximum operating period of 16 hours in every 24 during the hottest months. The coil in the breeding room consists of 90 linear feet of pipe having a surface area of 39.1 square feet, designed to maintain a temperature as low

as 75° F, with the same operating period during the hottest months. The total cost of the refrigerating equipment installed was $1354.

As has been previously stated, the object of constructing the breeding room underground was to reduce the normal temperature fluctuations and this was accomplished to an even greater extent than was expected. As shown in fig. 1, A and B, the temperature in the room during the week ended September 19, 1932, when the artificial control system was not in use, ranged from 73 to 81° F, as compared with that in the screened insectary which ranged from 63 to 97° F, or a range of eight degrees in the basement and 34 degrees in the screened insectary. The difference in the extremes of the two rooms would be more marked during the very hot or very cold months. Since the temperature has been artificially controlled during the hottest and coldest months, no records have been made of what would be the normal ranges during these periods.

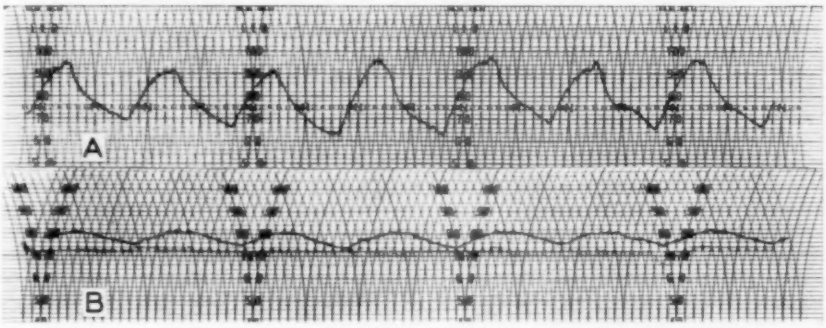

Fig. 1.—Temperatures recorded for week ending Sept. 19, 1932, Presidio, Tex. A.—Screened insectary. B.—Parasite breeding room (underground without artificial control).

For most of the insect rearing that has been done at Presidio, temperatures averaging 80° F, with a range of not more than six degrees, were desired. It was found to be unnecessary for the refrigerating coils to be in operation when the daily maximum outside temperatures did not exceed 100° F. During the week ended July 16, 1933, the daily maximum outside temperatures ranged from 100 to 109° F, with an average of 105.4°. The daily mean temperature averaged 89.6° F for the week. During this period the breeding room was maintained at 78 to 81°, and the number of times the refrigerating machine operated ranged from four to seven, with an average of five, daily operating periods. The length of the operating periods was not determined definitely, but casual observations and thermograph records indicate that the coils must have been operating on the average not more than two and one half hours daily.

The breeding room is equipped with humidity controls and heating devices similar to those described by W. A. Baker & K. D. Arbuthnot.[1] An electric heater consuming slightly less than 1 watt per cubic foot of air space was found to be sufficient, with considerable nonoperating

[1] Jour. Econ. Ent. 24(2): 444–50. April 1931.

periods, to hold the room at 78 to 80° when the outside temperatures were below 30° F. As previously stated, no records of what would be the normal daily range of temperature in the room were obtained during the extreme cold weather. Because of defective wiring, however, the heater became disconnected several times, and the thermograph records showed that the heat was very slowly conducted out of the room. The heater was off 16 hours from 4 p. m. to 8 a. m. December 12–13, 1933, and the temperature dropped gradually from 80 to 58° F. The outside temperatures during this period dropped from 80 to 29° F. The maximum for the day was 80° and was reached between 3 and 4 p. m. The temperature dropped to 56° by 6 p. m. and to 29° F, the minimum, by 5 a. m.

COTTON STATES BRANCH

PAPER-READING SESSION, EIGHTH ANNUAL MEETING

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NOTES ON LIFE HISTORY, HABITS AND DISTRIBUTION OF *HETERODERES LAURENTII* GUÉR.

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The wireworm *Heteroderes laurentii* Guér. was recognized as an economic pest in 1927. Life-history studies have revealed that the species has a one-year cycle. Data presented show the present known distribution, seasonal peaks of egg deposition and pupation, crops attacked, and habits of larvae and adults. Notes on flight, hibernation, field populations and natural enemies are also given.

The wireworm *Heteroderes laurentii* Guér. was first recognized as a pest in the United States in Baldwin county, Ala., in 1927. During that season numerous complaints were received from sweet potato growers of that district concerning wireworm injury. An investigation of these reports showed this species to be the principal offender.

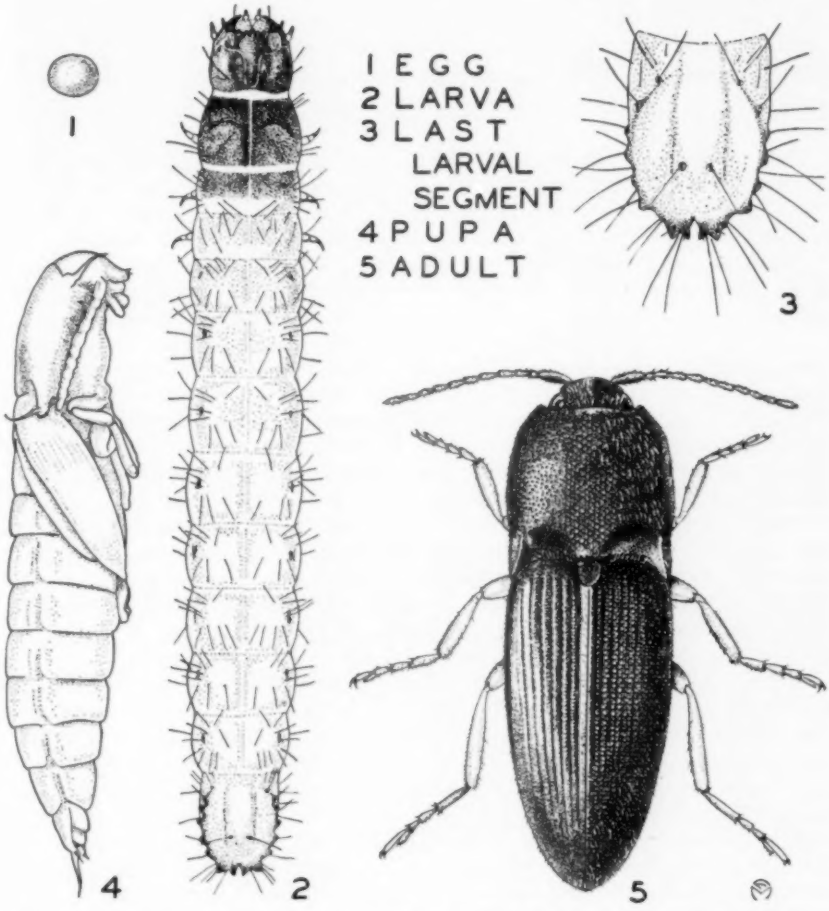
It is not known just when this insect gained entry into this country. H. P. Loding of Mobile, Ala., reports collecting adults of this species at that place in 1912 and at intervals since that date. The next locality record is the one from Baldwin county in 1927. The pest is probably of South or Central American origin, as the original description of this species by Guérin-Méneville[1] was made in 1838, from specimens collected at Lima, Peru.

Distribution

Alabama.—As already mentioned, this insect was recorded from Mobile county in 1912 and from Baldwin county in 1927. More recent scouting has shown it to be present in Escambia and Washington counties in 1931, and in Monroe, Conecuh, Covington, Geneva and Houston counties in 1932.

[1] Guérin-Méneville, F. E. 1838. Insectes du voyage de la Favorite. Mag. Zool. 8, class IX. 80 pp., illus.

Florida.—An unpublished report in the files of the Insect Pest Survey of the U. S. Bureau of Entomology gives one record of the insect's occurrence at Fort Myers in 1927. Larvae collected in Jackson and Holmes counties in 1930 have been tentatively identified as this species. Adults



Figs. 1–5.—Stages in the life history of the wireworm *Heteroderes laurentii* Guér.

were discovered in Escambia and Santa Rosa counties in June, and at Gainesville, in Alachua county, in December 1931. Specimens were collected in Walton and Okaloosa counties in 1932.

Mississippi.—Specimens were collected in Harrison county in 1928, in George county in 1929, in Jackson county in 1930 and in Greene county in 1931.

South Carolina.—Four adults collected in the summer of 1932 at

Charleston, S. C., by W. J. Reid were examined and determined as *Heteroderes laurentii* Guér.

No scouting has been done in Georgia but this insect was found to be plentiful in Houston county, Ala., about 20 miles from the Georgia line. It is interesting to note that careful scouting over a period of several years has failed to reveal the presence of this insect west of Harrison, George and Greene counties in Mississippi. This would indicate that the insect has not spread farther westward.

Description

Egg.—The egg, fig. 1, is pearl colored, oval, and slightly less than one half mm. long. The surface is smooth and shiny, and when newly laid the egg is somewhat sticky. Infertile eggs are often paler or more yellowish than fertile eggs, and are often undersized.

Larva.—The larva, fig. 2, is golden or yellowish brown in color. Full-grown specimens are 16 to 18 mm. long and 3 mm. broad, and slightly compressed dorso-ventrally. The head and first segment are a deep mahogany brown, the mandibles are black and the paired series of marginal lobes on the dorsal side of the ninth abdominal segment, fig. 3, are darker than the other portions of the body. The plate of this ninth abdominal segment is flat, but the lobes curve or protrude slightly upward, giving it the appearance of being dish shaped. The notch or opening between the urogomphi is shallow and is approximately only one third as wide as each urogomphus. This appears to be a generic character.

Pupa.—The pupa, fig. 4, is 12 to 14 mm. long, creamy white, with legs, wings and antennae well developed and free. The eyes are dark and the wings protrude outward from the body. The pupa is very active and wriggles the abdomen vigorously when disturbed, frequently turning completely over several times. The tip of the abdomen bears two slender spines or cerci.

Adult.—Guérin-Méneville described the adult, fig. 5, as being 8 to 9 mm. long, and 3 to $3\frac{1}{4}$ mm. broad, dark brown and velvety above and below, with the antennae and legs pale yellow. The joints of the antennae are inversely conical, with the first joint very long and curved, the second much shorter, the third longer than the second, and the others somewhat longer and approximately equal. The thorax is square, broader than the elytra, somewhat flattened in the middle, with the posterior angles prolonged and unicarinate. The thorax bears both coarse and fine punctations, and has a silky appearance produced by the fine down with which it is covered.

The females are somewhat larger and more robust than the males. The antennae of this sex are short of the thorax, or do not extend beyond the posterior angles, whereas those of the males extend as far as or past the hind thoracic angles.

Life and Seasonal History in Southern Alabama

The eggs are laid on or near the surface of the soil. The number of eggs laid by individuals varies considerably, depending upon temperature,

humidity and other factors. In the laboratory the highest number of eggs obtained from an individual was 58, the average for all beetles depositing being 11.5. Seventeen eggs have been dissected from the abdomen of one female. In the field more eggs are deposited under trash, which provides coolness, dampness and protection from light, than are deposited in the cleanly cultivated fields or in turf or grassland. During the four years of these observations, 1929–32, inclusive, the first eggs have been found in May of each year, with the highest peak of deposition occurring in June, while eggs in smaller numbers have been obtained throughout the summer months.

The time required for the incubation of the eggs is shown in table 1, which gives the records for the four years.

Table 1.—Time required for incubation of eggs of *Heteroderes laurentii*.

Year	Number of Eggs	Minimum *days*	Maximum *days*	Average *days*
1929	40	3	13	8.8
1930	38	6	18	9.1
1931	17	7	19	9.8
1932	40	3	20	10.1

The young larvae make a straight slit in the eggshell and through this they emerge. Although they are delicate and many perish from dryness, they are very active, crawling around freely, and are likely to begin feeding the day they are hatched. Normally they grow rapidly, attaining most of their growth within the first 8 to 10 weeks. By the end of November spring-hatched and summer-hatched larvae are practically full grown. Very little growth occurs during the winter months, December to February. Larvae hatching during the spring and summer of one year pupate during the spring of the following year. During the last few weeks

Table 2.—Length of pupal period of *Heteroderes laurentii*.

Year	Pupae	Minimum *days*	Maximum *days*	Average *days*
1929	44	6	12	8.5
1930	4	9	11	10.3
1931	66	4	13	7.6
1932	52	6	16	10.7

prior to pupation they consume large quantities of food, become more robust, and immediately preceding pupation appear thicker and shorter. The larval period of a few individuals was noted during three seasons and was found to range from 278 to 336 days, with an average duration of 315.6 days.

Pupation occurs in an earthen cell in the top layers of the soil, the majority of the pupae being found within three or four inches of the surface. In observations in both laboratory and field the earliest pupation occurred in April, the peak of pupation occurred in May and early June, while a very small percentage pupated during the months of July and August. The observed pupal periods for the four years are shown in table 2.

General Field and Laboratory Observations

Larval feeding habits and crops attacked.—Although it is possible for larvae of this insect to go several months with very little food, they feed more or less regularly and continuously in the fields during the spring, summer and fall. They feed on humus in the soil, tubers and root crops, on roots of various plants and on sprouting grain.

Figs. 6, 7.—Injury to sweet potatoes by the feeding of *Heteroderes laurentii* larvae.

The first discovered damage by this insect was to late-summer-harvested and fall-harvested sweet potatoes, figs. 6, 7. Since that discovery the insect has been noted as a serious pest to both spring-harvested and fall-harvested white potatoes, figs. 8, 9, spring-planted corn and oats; and farmers have reported it as doing rather serious injury to lespedeza and snap beans. The most notable injury is to root crops and potatoes.

In 1931 the white potato crop in Baldwin county, Ala., was very seriously damaged. Many car lots loaded for market showed injury as high as 25 per cent.

The greatest damage to corn is in the sprouting stage, especially when sprouting during the last few weeks prior to the insect's pupation. The

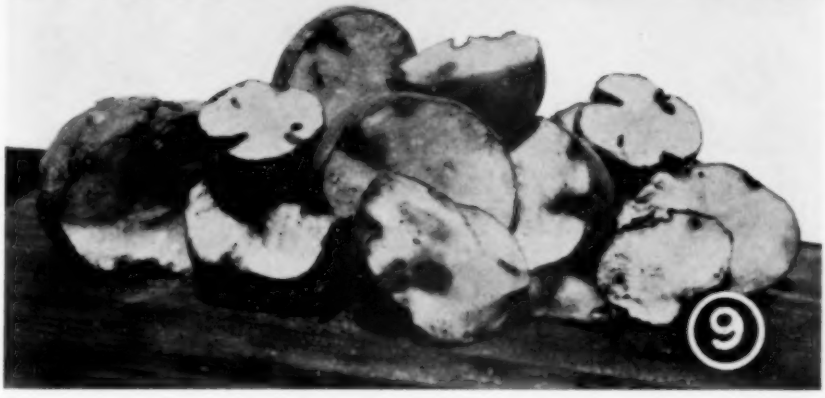


Fig. 8.—External appearance of damage to potatoes by larvae of *Heteroderes laurentii*. **Fig. 9.**—Tunneling in potatoes by larvae of this wireworm.

larvae are very fond of sprouting grain and often devour the entire germ, thus affecting the stand, fig. 10. When the seed has sprouted but before the grain has disintegrated, the larvae bore into the old decomposing kernel and attack the main root of the seedling, affecting the growth of the whole system. The result is a stunted, unthrifty plant, fig. 11.

Corn planted during March and April in southern Alabama usually appears more severely injured than if planted during February or about the middle of May. Corn is more seriously damaged when planted in hills two and one half to three feet apart than when sown more thickly in the drill. As many as seven larvae, and an average of five per hill, have been collected from experimental corn planted in hills. In rows where the seed is drilled six, eight or ten inches apart, the larvae rarely congregate in any

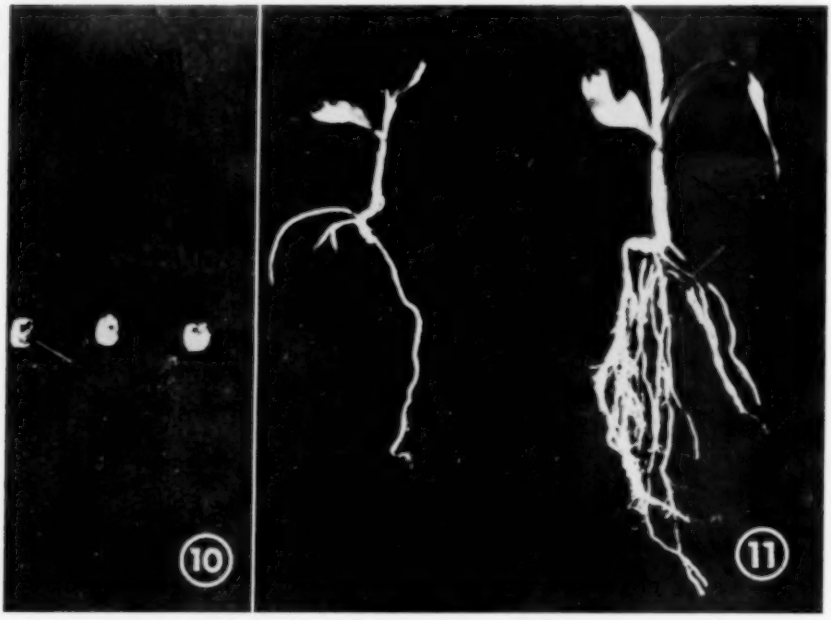


Fig. 10.—Feeding holes of wireworm larvae in corn. The germ is destroyed. **Fig. 11.**—Left, stunted cornstalk with root system nearly destroyed by wireworms; right, healthy, uninjured stalk of same age.

particular point, but are found singly up and down the drill, feeding on the nearest available food.

Although sifting reveals the presence of larvae in fields planted to cucumbers, cabbage, turnips, mustard and similar crops, these are ordinarily not so severely injured as sweet potatoes, white potatoes, corn and small grains. Fall-harvested sweet potatoes are more severely attacked than those harvested during July. Both spring-harvested and fall-harvested white potatoes are attacked.

For a number of years soil sifting has been conducted in order to determine the population of larvae in various plats and crops. In sifting for the recovery of these wireworms the unit of soil has been one square foot, four inches deep. The larvae are rarely found deeper than four inches. In some fields as many as 10 and 11 larva per square foot have

been recovered, indicating an enormous population per acre. The greatest numbers of larvae have been found in fields of cultivated crops. In plats planted to early Irish potatoes followed by late corn, larvae are very abundant. Through the seasons of 1930 and 1931 some of these fields have averaged 8.5 larvae per square foot, whereas grass and turf land at the same time averaged less than one larva per square foot. Fallow land has also shown less dense population than spring-cultivated and summer-cultivated fields. In March 1931, in plats where cabbage, corn, oats, rye and wheat were planted, the greatest numbers of larvae were found in the oats, rye and wheat rows. In 1931 windrows of old potato vines were left in the fields during the season for traps, and late-summer sifting showed as many as 30, and an average of 25, larvae per square foot in the soil under these old vines.

Wireworm populations have been found to be "spotted." In fields planted to the same crop, certain areas will yield more larvae per square foot than other parts of the field. In many instances there is no apparent difference in soil types, moisture content, drainage, etc. The authors have not been able to determine why this uneven distribution occurs, but believe that it may be due to some factor that influences the adults in selecting site for depositing their eggs.

Habits of adults.—Immediately after emergence adults congregate in the fields where they have emerged, and are to be found hiding under trash, grass, rubbish, potato vines, etc. They seem to prefer a place where they are shielded from sunlight and heat and one where there is some moisture. Contrary to information gathered in connection with other species, there seems to be no evidence of a number of males congregating around an individual female, as collections in the field have shown practically equal numbers of males and females. The beetles remain comparatively inactive throughout the day, but come out at night for feeding and general activity. The adults generally are pollen feeders, and the corn crop furnishes the bulk of pollen during the summer season, although in the lower South the majority of coarse grasses and weeds that grow along fences, ditches, roadways, and in poorly cultivated fields furnish a great deal of pollen. In an outdoor insectary and in the fields beetles were not observed to fly to corn tassels at night, but were seen crawling freely about on the ground, where they were apparently feeding on pollen that had dropped from the tassels.

Hibernation.—For several years adult beetles have been collected under surface trash, grass, weeds, etc., in the fields during the winter months. In November 1929, 53 adults were put in a small outdoor hibernating cage. In April 1930 the cage was examined and five adults, or 9.4 per cent, were found alive. Two were males and two females, the other specimen being so mutilated that it was not examined. In November 1930, one small hibernating cage containing 15 adults and another containing 25 were placed out. On examination in April 1931 all the beetles in both cages were found to be dead. In January 1931, 12 beetles, four *Heteroderes laurentii*, two *Monocrepidius bellus* Say and six *Monocrepidius* sp., were placed in a hibernating cage, but none survived. In December 1931, 81 adults were placed in an outdoor hibernating cage.

On examination in April 1932, 27 live beetles, or 33.3 per cent, were recovered—15 males and seven females, the remaining five specimens not being examined. Adults which had hibernated have been kept alive in the laboratory until June 27, but no mating has been observed and no eggs have been obtained.

Flight of adults.—Soon after emergence, usually in June, a definite flight of adults begins, lasting several weeks. During the flight adults are collected freely at night around lighted windows and beneath street lights, where they are found sticking to the sides of walls or crawling around on the ground or sidewalk; but beetles have not been observed to fly directly to a light or to hover around it, as so many insects do. However, a few beetles have been caught in trap lights placed in cornfields where there were known to be thousands of beetles per acre. On June 19, 1931, four adults were collected at one trap light. Two were females, one was a male, and one was so damaged that it could not be properly examined. On June 25, 1932, five females were collected at a trap light. On June 19, 1931, nine females and three males were collected on the sidewalk and around plate-glass windows in front of the hotel at Foley, Ala.

During the day beetles show a strong negative phototropism and are content to remain quietly in hiding. When beetles are being handled in the laboratory they rarely attempt to fly but usually seek to crawl under the nearest object. Females almost invariably refuse to oviposit in a jar or cage exposed to light. Eggs are more readily obtained in the darkness of a tin box, or in a lantern-globe breeding cage if leaves or pieces of dark paper are placed in the bottom to provide darkness and a place for hiding.

Natural enemies.—The most important enemies found were two toads, *Bufo quercicus* and *B. terrestris*. The stomach contents of a good many of these toads have been examined, and as many as four *Heteroderes laurentii* have been found in one stomach. Several larvae of *H. laurentii* were found in the stomachs of some of the toads, and a total of 47 insects were counted in the stomach of one medium-sized toad.

A comparatively large number of larvae bear a mite, a species of Tyroglyphidae,[2] which has been determined as a "rider," doing no damage to the insect and merely taking advantage of a means of transportation by attaching itself to the larvae. Another mite, *Histiostoma*[3] sp., has been found on the larvae, but little is known of its life history. Nematodes have also been found in larval specimens, but neither the species nor the extent of damage done has been determined. Many larvae in the laboratory die from a bacterial disease which causes the specimens to turn black and disintegrate rapidly, the body fluid becoming thick and ropy.

[2] Identified as to family by H. E. Ewing.
[3] Identified as to genus by H. E. Ewing.

MR. P. A. GLENN, Chief Plant Inspector of the Illinois Department of Agriculture for more than twenty years, was compelled to give up his duties recently on account of ill health. Since April 1, H. F. Seifert has been in charge of the work.

EASTERN BRANCH

PAPER-READING SESSION, SEVENTH ANNUAL MEETING

Baltimore, Md., November 1935

PRELIMINARY REPORT OF TRAP-LOG STUDIES ON ELM BARK BEETLES[1]

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Scolytus multistriatus Marsham, the European elm bark beetle, and *Hylurgopinus rufipes* (Eichoff), the dark native elm bark beetle, have been identified in America as carriers of the Dutch elm disease organism. Up-to-date sanitation and proper care of the elms have been the only methods of control. Trap logs have been used in forestry as a means of reducing bark beetle populations[2] and they would be useful in a number of ways in the control of these pests and also other beetles infesting elm bark (1) to offer an accessory means of reducing beetle populations in an area, (2) to scout an area for the presence of the beetles, (3) to determine the status of beetle populations from year to year in order to measure the efficiency of sanitary measures now being practiced.

The present report covers elm trap-log data obtained during the summer of 1935. The objective of the experiments being reported was to determine the best time and methods of exposure which would give the maximum number of beetles in the logs. The experiments were located in an extensive swamp area near Patterson, N. Y. The tree cover consisted mainly of maples, elm, ash and alder; wild allspice (Lauraceae), Veronica and a few other shrubs made up most of the underbrush. The floor of the swamp was covered mainly with royal ferns, skunk cabbage and a species of tall swamp grass. Clearings among the trees were scattered over the swamp; some covered but a few square rods while others covered several acres.

METHODS

Main experiment.—From 30 to 100 logs, 3 feet in length and $3\frac{1}{2}$ to $8\frac{1}{2}$ inches in diameter, were cut at approximately two-week intervals from April 25 to September 15. In order to keep the logs out of water and above the vegetation of the swamp floor they were placed on racks of sapling elm, about three feet from the ground. The racks were numbered consecutively and were located 35 to 200 yards from each other. These logs will be referred to as the main series. This experiment was planned to determine the best time of cutting to obtain maximum infestation.

Light conditions of the main experiment.—Racks I, II and IV were

[1] The author wishes to express his appreciation to Dr. P. A. Readio for his help with the project and for his review of the manuscript.

[2] **Graham, S. A.** 1929. Principles of Forest Entomology, pp. 80–1, McGraw-Hill Book Co., New York.

surrounded by trees, the canopy over racks I and IV being 12 to 15 feet above them. The undergrowth was principally grass and ferns. Rack III

Fig. 1.—Environments of racks I, III, V and IX. The photograph of rack IX also shows the rack of vertical logs discussed in the text.

was partially beneath two tall elms but was mainly shaded by a thicket of alders on the south side. The axis of the rack ran east and west. Alders were cleared from the north side of the logs for a distance of 10 to 12 feet.

Racks V, VII, IX and X were in small clearings which were partially shaded by elms and maples 35 to 45 feet in height. Rack VI was on the south edge of an extensive clearing so that most of the surrounding environment was unshaded the greater part of the day; the rack was shaded on the west side by trees. Its axis ran north and south. Rack VIII was at the north end of an irregular row of trees which separated two clearings. It was in about as much shade as rack II but the latter was surrounded by a dense tree covering. Photographs of racks I, III, V and IX are shown in fig. 1.

The brightness of each rack, except IX and X, was computed in August in candles per square foot with a Weston exposure meter. Readings were taken at every tenth log on the rack at half-hour intervals from 9 a. m. to 3 p. m. and an average computed.

Paraffined logs.—At each cutting of the main series the ends and cuts in the bark of one or two pairs of logs were covered with paraffin. It was believed that paraffing the logs might prolong their attractive properties.

Moisture determination.—The per cent water content of the phloem region of each log of the main series was obtained from the wet and dry weights of two bark samples, two inches in diameter, taken from the upper half of the log in a region as free as possible of insects.

Check experiment.—Pairs of logs taken from the cuttings of June 28, July 14, August 1 and August 16 were placed with each of the cuttings made previous to each of these dates. For the June 28 and July 14 cuttings, logs from two different trees were used for a pair; the pairs of the August 1 and August 16 cuttings were from single trees. These will be called the check logs. The data of these logs not only gave a measure of the effect of location on beetle infestation but also were accessory data to the main cutting experiment.

Horizontal-vertical experiment.—Alternate logs from each of the four trees of the August 31 cutting were divided between two racks; a set of 16 was used for rack IX while 15 were placed in an upright position on a vertical rack. The axis of this rack ran north and south so that one side of the logs received the most light in the morning and the other the most in the afternoon. The logs on the horizontal rack, of course, had only one side exposed to sunlight. *Scolytus* usually enters the upper half of a horizontal log but will occasionally enter the lower half, hence there is a possibility that a log lighted on both sides will attract more beetles. Infestation records were taken from eight logs.

Isolated logs.—One or two pairs of logs from each of the main cuttings were isolated at distances of 50 to 300 yards from the racks. These logs were placed in the crotches of trees approximately five feet from the ground or on fallen logs that lay above weeds. The objective of this experiment was to determine if isolated logs were more attractive to the beetles than groups of logs.

Small groups.—A set of 13 logs, cut April 25, was placed in two groups within 50 feet of each other. Some were stacked tepee-fashion beneath a sapling maple while others were in a horizontal position on the ground.

Suspended logs.—Two logs 4 inches in diameter, cut April 25, were

suspended by a wire 20 feet above the ground in an elm tree. There is some possibility that beetle infestation might be influenced by the distance which a log is from the ground.

Lath-shaded logs.—Logs 6 feet long, cut May 8, May 22 and June 7, were taken to a clearing and placed on the ground. Lath shelters were constructed over them so that 75, 50 and 25 per cent of the upper surfaces were exposed to the sun. Weeds were kept clear of the cages. A fourth set was placed in complete shade, those cut May 8 were in the deep shade of trees while those cut May 22 and June 7 were beneath lath. These logs gave information concerning light and location.

Girdled trees.—Trees were completely and three-quarters girdled five times from May 15 to July 20 to obtain information about the condition of the tree in relation to beetle infestation and to learn if standing trees are more attractive to beetles than logs.

Data records.—Infestation records have been obtained from approximately 475 logs. At weekly intervals, from June 5 to September 30, two logs from each rack were stripped of their bark, records made of the number of beetles present and life history notes were taken. Galleries and entrance punctures were used to compute average infestation. Logs not included in the weekly series were examined late in August and during September. The analysis of the variance as outlined by Snedecor[3] was used to determine significance.

Experimental Results

Five species of beetles, *Saperda tridentata* Olivier, *Hylurgopinus rufipes* (Eich.), *Scolytus multistriatus* Marsham, *Scolytus sulcatus* Le Conte, and *Magdalis* sp., came to the logs. At times *Saperda* larvae outnumbered *Hylurgopinus* tenfold, *Hylurgopinus* was about three times more numerous than *S. multistriatus*, and *S. sulcatus* came in very small numbers to racks IV and V. Under the proper conditions *Magdalis* was apparently more numerous than *Saperda*.

Infestation in relation to time of cutting.—*Hylurgopinus*. The data collected this season, table 1, show that there was an average infestation of 40.5 *Hylurgopinus* galleries per log for the April 25 cutting and a maximum average of 50 per log for the May 15 cutting. The average for the May 30 cutting drops to but 5 galleries per log; after this date the averages range from none to 2.8 galleries per log. A correlation seems to exist between the per cent of non-infested logs and the degree of infestation.

While the check logs of racks I and II, table 2, continued to attract more *Hylurgopinus* throughout the summer than the logs on the other racks, yet the infestation of the summer-cut logs is considerably lower than for the spring-cut logs. With the possible exception of racks III and VII, there is not a great deal of difference in the number of *Hylurgopinus* infesting the check logs or main series, either between different racks or between different cuttings. The check-log data further establishes the

[3] **Snedecor, Geo. W.** 1934. Calculation and Interpretation of Variance and Covariance. 96 pp. Collegiate Press, Inc., Ames, Iowa.

fact that late April and mid-May-cut logs were most attractive to *Hylurgopinus*.

Theoretically there should have been an increase in the number of *Hylurgopinus* entering the logs during August and September since large numbers that had developed from spring-laid eggs were emerging at this time of the year. The few that did enter either made only one short lateral tunnel without laying eggs or merely punctured the phloem and then left the log.

Table 1.—Beetle infestation for successive cuttings of logs from April 25 to September 15, and brightness values for each rack.

Date Logs Were Cut	Rack Number	Average Candles per sq. Foot	Number Logs Examined	Hylurgopinus Total galleries	Hylurgopinus Galleries per log Mean number	Hylurgopinus Galleries per log Max.	Hylurgopinus Galleries per log Min.	Scolytus Total galleries	Scolytus Galleries per log Mean number	Scolytus Galleries per log Max.	Scolytus Galleries per log Min.	Per Cent of Non-infested Logs Hylurgopinus	Per Cent of Non-infested Logs Scolytus
4/25	I	11	44	1785	40.5	95	3	15	.3	5	0	0	91.2
5/15	II	17	37	1851	50	247	7	8	.2	6	0	0	94.7
5/30	III	16	31	194	5	27	0	24	.6	6	0	36	73.7
6/14	IV	10	35	40	1.1	14	0	102	3.1	17	0	63	42.4
6/28	V	29	36	102	2.8	9	0	215	5.9	28	0	19.4	13.8
7/14	VI	38	24	21	.8	6	0	50	2.8	19	0	54.2	33.3
8/1	VII	28	16	72	.5	3	0	308	19.9	35	5	68.8	0
8/16	VIII	15	12	76	.5	3	0	149	12.4	28	1	91.7	0
8/31	IX		8	7	.9	2	0	66	8.2	17	0	50	12.5
9/15	X		8	0	0	0	0	2	.2	1	0	100	75

Scolytus. The season's data, table 1, for the main cutting show that the infestation for April and May-cut logs was very low; after these cuttings it increased, with the exception of that of July 14, until the maximum average infestation of 19.9 *Scolytus* galleries per log was reached in the August 1 cut of logs. After this time the number of galleries per log decreased until but .2 gallery per log was found in

Table 2.—Average beetle infestation of check logs.

Rack No.	Galleries per Check Log on Cutting Dates: June 28 H*	June 28 S†	July 14 H	July 14 S	Aug. 1 H	Aug. 1 S	Aug. 16 H	Aug. 16 S	Average for Each Rack: Check logs H	Check logs S	Main series H	Main series S
I	3.5	0	3.5	0	22	0	21.5	0	12.6	0	40.5	.3
II	21	1.5	5.5	9.5	2.5	0	4.	0	8.4	2.5	50	.2
III	.5	2	0	12	2	12.5	1	15	.9	10.4	5	.6
IV	5	0	0	0	0	0	0	2	1.2	.5	1.1	3.1
V	3.5	4.5	3	13	1	25.5	0	27	1.9	17.5	2.8	5.9
VI			1	0	.5	3.5	0	2	.7	1.8	.8	2.8
VII					.5	26.5	8	8.5	4.2	17.5	.5	19.9
Average for Each Cutting Date												
Check logs	6.7	1.6	2.3	5.7	4	9.7	4.9	7.8				
Main series	2.8	5.9	.8	2.8	.5	19.9	.5	12.4				

* *H* = *Hylurgopinus*.
† *S* = *Scolytus*.

the September 15 cutting. Undoubtedly, the September average would have been lower had more logs been examined. As with *Hylurgopinus*, there seems to be a definite correlation between low infestation and a high per cent of non-infested logs.

The check logs on racks II, III and V, table 2, averaged from 2.3 to 11.6 more *Scolytus* galleries than the older logs on these racks. On rack IV few *Scolytus* were attracked to the checks, while on racks I, VI and

VII the infestation in both check and main series was about the same.

When the differences in infestations between cuttings are compared, the check logs, though the infestations were lighter, seem to correlate with the main series. Thus in general, the data show that logs cut August 1 attracted the most *Scolytus*.

Infestation in relation to location and degree of shade.—*Hylurgopinus.* The trends of the data of table 2 indicate that other factors besides that of time of cutting influence *Hylurgopinus* infestation. One seems to be shade; *Hylurgopinus* usually enters the the shady side of a log whether it is vertical or horizontal in position. More were attracted to the check logs of racks I and II than to the check sets of other racks. As described under METHODS and as can be seen by the brightness measurements in table 1, both of these racks were in dense shade. However, rack III, while its environment was different, was apparently in as much shade as rack II, and Rack IV's environment was nearly like that of rack I, yet the infestations of the logs on these racks were low in comparison.

Scolytus. Scolytus' preference for semi-sunny spots is indicated by its tunnels usually being located on the brighter side of logs and also by the data trends. In the check log series racks I, II and IV attracted few or no *Scolytus* even though the logs were cut at the proper time. Rack III seemed to be favorably located even though apparently shaded as much as rack II. Possibly the clearing in front of the rack and the lack of branches overhead made the location brighter than the photometer readings indicate. Racks V and VII were about equally shaded according to the brightness readings. The check logs on each rack averaged 17.5 galleries per log.

The set of check logs on rack VI averaged 1.8 *Scolytus* galleries per log as compared with the 17.5 per log for each set on racks V and VII. Also the *Scolytus* average of the main series of rack VI is 2.8 galleries per log, while that of rack V is 5.9 and that of rack VII is 19.9 galleries per log. The differences are mathematically significant. The set of check logs from the cutting of rack VI on other racks averaged 5.7 galleries per log. The lowered infestation of rack VI is interpreted as being due to too much sunlight on the rack and its environment.

The period of attractiveness of an individual log.—*Hylurgopinus.* Since the beetles began entering the logs the last week in May, the logs cut April April 25 had remained attractive for a month. The logs cut May 15 attracted 10 more beetles per log. This difference was not due to sampling and might be indicative that April-cut logs were beginning to lose their attractiveness to the beetles.

Scolytus. The first beetles appeared in the logs on rack III about June 20. The first beetles were found in the logs of rack I August 5. The length of the larval tunnels indicated that the beetles had entered the logs three weeks to a month before this time. Thus these individual logs had remained attractive for roughly 10 weeks. Some of the logs cut June 28 for rack V seemed to remain attractive over a longer period than any of the logs cut on other dates. Observation showed that a few of the logs were being freshly infested at the end of six weeks, while one log was entered at the end of 11 weeks. Observations of the August-cut logs in-

dicated that the beetles began entering from one to six days after cutting. But few were entering a month after the logs were cut.

Period of attractiveness of a cutting.—While individual logs may remain attractive for some time, yet the data of this summer indicate that a whole cutting does not continue to attract beetles very long after its initial infestation.

Hylurgopinus. The first logs examined during the first two weeks of *Hylurgopinus* presence in the field average 44 galleries per log for four logs from rack I and 70 per log for four from rack II; both averages are higher than the general averages for all the logs examined from each rack. There was no systematic rise or fall in the infestations during the rest of the summer; one week the number of galleries might be much less than the average and the next it might be much higher. New entrance tunnels, often deserted, were not found in the logs for a period longer than three weeks after the initial infestation.

The number of maternal tunnels examined for eggs from June 6 to August 7 was 331 for rack I, 305 for rack II, and 90 for rack III. When

Table 3.—Average number of *Hylurgopinus* eggs per tunnel.

Rack No.	Date of Examination									
	6/6	6/12	6/20	6/26	7/1	7/10	7/17	7/23	7/30	8/7
I	12.6	22.1	40.2	39.5	32.5	21.9	9.5	6.5	.2	0
II	15.2	39.1	64	23.5	18.7	9.8	1.7	.7	0	0
III		6.1	14	32.3	58.4	4	8.8	0	0	0

the average number of eggs per tunnel was plotted against time, the curves showed that very few or no beetles entered the logs for a very long period after initial infestation. These data are presented in table 3.

If *Hylurgopinus* had continued to come to the logs for a long time, either polymodal curves would have been obtained or the maximum number of eggs would have remained more or less constant much longer than it does in these data. The curve of rack I was flattened for two weeks, which might be indicative of beetle entrance in these logs over a longer period than in those of racks II and III, or it might be the result of lower maximum temperatures at this situation.

Scolytus. If each cutting of logs had remained attractive to *Scolytus* for a very long period of time some of those cuttings made before August 1 should have attracted as many or more beetles than the August cutting. As tables 1 and 2 show, this was not true but instead each cutting, with the exceptions previously discussed, attracted a few more than the previous one until the early August population peak was reached; then the beetle numbers began to wane. Since the cuttings were made approximately two weeks apart we may reason that most of the attractiveness had been lost by the time for the next cutting.

Infestation of paraffined logs.—The infestation of paraffined logs did not differ significantly from the main series either for *Hylurgopinus* or *Scolytus*.

Infestation in relation to water content of phloem.—The water content of the phloem region, table 4, did not vary as greatly during the early summer as it did later in the season. Frequent showers during June and July perhaps replaced most of the moisture lost by the logs. There was a gradual average decrease of 15 per cent in the water content of the

phloem from June 12 to September 27. These data do not seem to correlate with beetle infestation.

Infestation of horizontal and vertical logs.—*Scolytus.* The vertical logs averaged four *Scolytus* galleries per log while the horizontal logs averaged 8.2 galleries per log. The west side of the vertical logs averaged 2.9 galleries and the east side 1.1 galleries; the upper half of the logs averaged three galleries while the lower averaged one gallery per log.

Table 4.—Water content of the phloem region of elm logs.

Date Sample Taken	No. Bark Samples	Per Cent Water Content per Log		
		Min. ave.	Max. ave.	Average
June 12	12	33.5	52.1	44.6
June 19	16	45.7	51.1	48.3
June 26	16	44	53	48.2
July 1	20	35.8	47.6	41.9
July 10	20	37.4	47.5	44
July 17	24	36.9	48	43.8
July 23	24	39.8	47.9	44.9
July 29	24	36.1	48.5	42
Aug. 5	28	37.6	44.6	40.7
Aug. 13	28	27.6	46.7	39.1
Aug. 20	32	25.6	47	38
Aug. 27	32	23.9	43	34.6
Sept. 4	30	30.1	48.3	40.5
Sept. 10	30	22.5	49.1	39.2
Sept. 17	28	24.5	55.2	36
Sept. 27	26	17.7	45.9	33.8

Infestation of isolated logs.—The 27 isolated logs contained 171 *Hylurgopinus* and 24 *Scotylus* galleries. The data are presented in table 5.

Hylurgopinus. For the most part the isolated logs were located more favorably for *Hylurgopinus.* With the exception of the logs cut May 15 the infestation trends seem to be correlated with the main series. The

Table 5.—Infestation of isolated logs.

Date Cut	No. Logs	Hylurgopinus			Scolytus		
		Total galleries	Ave. per log		Total galleries	Ave. per log	
			Isolated logs	*Main series*		*Isolated logs*	*Main series*
April 25	5	128	25.6	40.5	15*	3	.3
May 15	4	3	.7	50	0	0	.2
May 30	4	10	2.5	5	0	0	.6
June 14	4	0	0	1.1	0	0	3.1
June 28	5	25	5	2.8	1	.2	5.9
July 14	3	1	.3	1.3	8†	2.3	2.9
Aug. 1	2	4	2	.5	0	0	19.9

* Infestation of two logs at one location in partial shade.
† Infestation of two logs on top of a stump in less shade than the logs cut April 25.

infestation of the first two cuttings would indicate that isolated logs were not as attractive as groups of logs; however, the infestation of later-cut logs can be interpreted to mean that probably there was no actual difference between the isolated and main series logs.

Scolytus. Since the logs were located unfavorably for *Scolytus*, with the exception of two of the logs cut April 25 and those cut July 14, no interpretation should be given to these data. It is interesting that the two favorably located logs, cut April 25, attracted as many *Scolytus* as the 44 heavily-shaded, racked logs.

Infestation of small groups.—The four tepee-stacked logs contained 159 *Hylurgopinus* galleries and no *Scolytus*, the inner surfaces being in-

fested where there was the least exposure to light. The four horizontal logs and the five other nearby logs attracted only *Saperda*.

Infestation of suspended logs.—Each of the suspended logs was infested by 250 *Magdalis* larvae and about 50 *Saperda*. No *Hylurgopinus* or *Scolytus* entered.

Infestation of lath-shaded logs.—The partially shaded logs cut May 8 contained two *Hylurgopinus* galleries; the two completely shaded logs 108. The eight logs cut May 22 contained five *Hylurgopinus* galleries, four of which were in the completely shaded logs. Those cut June 7 did not attract beetles. No *Scolytus* came to any of these cuttings. Probably temperature and light made these logs unattractive.

Infestation of girdled trees.—No beetles were found in any of the 10 trees examined.

Infestation in relation to size of log.—The data from logs infested under all conditions were used to determine the effect of size of the log

Table 6.—Infestation in relation to size of log.

	Hylurgopinus			Scolytus		
Diameter in inches	No. logs	No. galleries	Ave. no. galleries	No. logs	No. galleries	Ave. no. galleries
4	56	1202	21.4	34	214	6.3
5	67	989	14.7	50	372	7.4
6	54	1509	27.9	34	309	9.1
7	26	507	20.1	23	204	8.9
8	9	328	36.7	11	178	16.3

upon *Hylurgopinus* and *Scolytus* infestation. They were divided arbitrarily into five classes: $4 \pm \frac{1}{2}$, $5 \pm \frac{1}{2}$, $6 \pm \frac{1}{2}$, $7 \pm \frac{1}{2}$ and $8 \pm \frac{1}{2}$ inches in diameter. Table 6 presents the data.

An analysis of the variance showed that the differences between the various classes were not significant. The interpretation is that a difference of $3\frac{1}{2}$ to $8\frac{1}{2}$ inches in the diameter of a log does not influence either *Hylurgopinus* or *Scolytus* infestation.

Summary.—The largest numbers of *Hylurgopinus* came to early spring-cuts logs while the largest numbers of *Scolytus* came to early August-cut logs.

For both species of beetles there was a correlation between a low degree of infestation and non-infested logs.

Logs in deep shade attracted the most *Hylurgopinus* while those in brighter locations attracted the most *Scolytus;* logs in too bright a location were not as attractive to *Scolytus* as those that were semishaded.

In the experiment reported, vertical logs attracted only half as many *Scolytus* as the horizontal.

Individual logs apparently remained attractive to *Hylurgopinus* and *Scolytus* for a longer period than a whole cutting.

Under the proper conditions isolated logs seemed to be about as attractive to *Hylurgopinus* as groups of racked logs.

Logs in clearings under lath shelters were not attractive to either *Hylurgopinus* or *Scolytus*.

Suspended logs attracted many *Magdalis*.

Paraffin logs did not increase beetle infestation.

There did not seem to be any correlation between the moisture content of the phloem of logs and *Hylurgopinus* and *Scolytus* infestations.

No girdled trees were infested.

A difference of $3\frac{1}{2}$ to $8\frac{1}{2}$ inches in the diameter of a log did not influence either *Hylurgopinus* or *Scolytus* infestation.

OBSERVATIONS ON THE LIFE HISTORY OF *PLATYNOTA STULTANA* WLSM. ON GREENHOUSE ROSE

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An infestation of tortricid leaf rollers was found on roses in a greenhouse at Alexandria, Va., in September 1933. Dr. F. F. Smith, who examined the roses at that time and made the first collections, estimated that about 15 per cent of the 100,000 rose plants in the greenhouse were infested. Reared adults were identified by August Busck as *Platynota stultana* Wlsm., a species previously recorded only from Mexico and California.

A brief discussion of this finding, as well as the synonymy of this species, was recently published by Busck (*1*). The synonymy is as follows:

Platynota stultana Walshingham. 1884. Trans. Ent. Soc. Lond. p. 127.
Platynota chiquitana Barnes & Busck. 1920. Contr. Nat. Hist. Lepid. N. A. **4**: 213.
Platynota tinctana Woglum [not Walker]. 1920. Calif. Dept. Ag. Month. Bul. **9**: 341–2.
Sparganothis tinctana Essig [not Walker]. 1926. Insects of Western North America, pp. 737–8.

A series of reared offspring of the moths used in these studies, as well as a representative number of preserved larvae and pupae, has been deposited in the United States National Museum.

Host plants.—In addition to rose, the following plants in Mexico and California have been recorded as attacked by the larvae of this species:

Avocado, *Persea americana* Mill.
Bell pepper, *Capsicum* sp.
Carnation, *Dianthus caryophyllus* L.
Cherimoya, *Annona cherimola* Mill.
Cotton, *Gossypium* sp.
Cyclamen, *Cyclamen indicum* L.
Grapefruit, *Citrus grandis* Osbeck
Orange, *Citrus* sp.
Portulaca, *Portulaca grandiflora* Hook.
Red pepper, *Capsicum annuum* L.
Sugar beet, *Beta vulgaris* L.
Tomato, *Lycopersicum esculentum* Mill.
Walnut, *Juglans* sp.

It has also been found attacking chrysanthemums, *Chrysanthemum hortorum*, in the greenhouse at Alexandria, and incidental to these studies has been reared on fuchsia, *Fuchsia speciosa* Hort., and strawberry, *Fragaria* sp.

McGregor (*3*) has recently described the injury of the larvae of this moth to green oranges in southern California.

Experimental technique.—Since the biology of this species had not been investigated, the work herein reported was undertaken to obtain

life history data to be used as a foundation for control experiments on the infested roses. These studies were begun in October 1933 and continued until February 1934. The live material was kept in an incubator, where the temperature was held at a minimum of 70° F but usually ran up 2–5° during the warm part of the day. The relative humidity ranged from 70 to 80 per cent. These conditions were used because they approximate those maintained in commercial rose houses.

Data on egg production and adult longevity were obtained by confining a pair of moths or, in the tests for parthenogenesis, a virgin female, in a tubular window-screen cage 6 inches tall and $2\frac{1}{2}$ inches in diameter. The bottom of the cage was also of wire screen, and the top was closed with a piece of cheesecloth held in place by a rubber band. A small sponge or wad of absorbent cotton, kept moist with a sugar-water solution, was placed in each cage to furnish food for the moths. The cotton is preferable since it dries out less quickly.

An ordinary microscope slide was kept in each cage as suggested by Peterson (*5*), and on these the females readily oviposited. Oviposition of this moth seems to be governed by a tactile response, since eggs were always deposited on the smooth glass slide, and never on the rough screen of the cage. Complete and accurate egg counts were therefore possible.

The cages were examined daily, and the slides bearing eggs were removed and numbered with a china-marking pencil. The eggs were counted under a wide-field binocular, and the slides were then placed in a petri dish for observation on incubation.

Larvae for head-capsule measurements were reared in numbers in small glass jars in which an adequate supply of fresh rose leaves was kept.

The larvae used for determining the length of the larval and pupal periods were reared singly in glass vials one half inch by five inches. One-half inch or so of water was placed in each vial and a cotton plug put in above the water. A new-growth rose leaf or a petal was then inserted, and a freshly hatched larva placed thereon with a camel's-hair brush. The vial was plugged with cotton covered with cheesecloth. Each vial was labeled with the life history number of the group of eggs from which the caged larva hatched and with a letter to differentiate it from the other larvae of that group.

These vials were placed in test tube racks, set in the incubator, and examined daily. Fresh food was added as needed.

The types of cages used in these studies were described and illustrated in a recent publication by the writer (*4*).

Development of the egg: Appearance.—The eggs, which are deposited during the night, are laid in flat clusters, the individual eggs overlapping shingle fashion. Usually all the eggs for one night are laid in one group. The cluster is covered and the individual eggs fastened to one another and to the surface on which they are laid by the clear, cement like secretion of the colleterial glands. On greenhouse roses the egg clusters are deposited on the under side of the leaves.

The individual eggs are flattened, oval in outline, and with the dorsal side convex. The chorion is transparent and is marked with very fine, raised lines—the outlines of the cells of the follicular epithelium, which

form minute hexagonal areas. The egg contents are pale green, which gives the egg cluster a color similar to that of leaves and makes them difficult to find in nature. Single eggs measure from .9 to 1 mm. on the long axis and from .6 to .7 mm. on the broad axis.

The embryonic development of the eggs on glass slides can be readily observed. As the larvae develop, the coloration of the egg cluster becomes darker. A day or so prior to hatching the young larvae are clearly visible through the chorion. They are curved head to tail, the head pointing either right or left.

Incubation.—A total of 2508 eggs were observed for the length of the incubation period. Of this number 2381, or 94.94 per cent, hatched. The data for the incubation of these eggs are summarized in table 1.

Table 1.—Length of different stages and total longevity of *Platynota stultana* on rose at 70° F.

Stage of Insect	Individuals Observed	Length of Period, Days		
		Maximum	Minimum	Average
Egg	2381	11	8	9
Larva	70	47	19	31.1
Pupa	73	11	7	9
Egg to Adult				
Females	37	64	41	49.2
Males	31	58	37	48
Both sexes	68	64	37	48.6

Hatching.—In hatching, the larva chews an opening in the chorion with its mandibles. As soon as its head is outside, the larva begins spinning a silken foothold for its thoracic legs by moving its head from side to side, and continues this until hatching is complete. By means of this foothold and of muscular pulsations of the body the larva is able to get free of the shell in a very short time. Hatching of all larvae from a given cluster of eggs occurred within a few minutes in many observed cases.

Larva: Habits and appearance.—The young larvae are negatively geotropic, and when hatched in confinement they always go to the top of the cage. On greenhouse roses they are found in the new terminal growth, and often in the flower and the upper axial leaf buds.

Besides tying together and rolling the leaves in which they feed and hide, the larvae also spin silken threads over any surface on which they walk, and when disturbed they drop on a silken thread.

The larvae are not gregarious and are apparently rather quarrelsome. On infested plants only one larva is found in a leaf or bud. They can be reared in numbers in cages if sufficient leaves are present to prevent too frequent contact between the larvae. If, however, two or more are confined on one leaf in a small cage, usually only one survives. It was observed that when two larvae meet under these conditions they are apt to bite at one another. Wounds inflicted in this manner doubtless explain the death of the extra ones. No cannibalism was observed.

Newly hatched larvae are from 1.4 to 1.8 mm. in length. Full-grown larvae may reach a length of 18 mm., although the average length of 50 mature larvae measured was 12.99 mm.

The newly hatched larvae are yellowish white, with the head and pro-

thoracic shield brown. As the larvae develop they become darker and although there is considerable variation they are usually yellowish to brownish green, the head and prothoracic shield remaining brown. A median dorsal ragged stripe runs the full length of the body. This is really a clear area in the body wall, but the dorsal blood vessel showing through gives it the appearance of a brown stripe. The pulsations of the heart can be readily observed. The setiferous tubercles are chalky white and show up prominently.

The larvae normally taper slightly toward the ends, although just previous to a molt the head is much narrower then the rest of the body and just following the ecdysis, as well as in newly hatched larvae, it is wider.

Number of instars.—The leaf-rolling habit of the larvae makes it difficult to determine the number of instars by direct observation. For this reason use was made of Dyar's rule (*2*) to determine the number of molts.

Table 2.—Width in millimeters of head capsules of larvae of *Platynota stultana*.

Instar	Calculated			Measured[1]		
	Maximum	Minimum	Average	Maximum	Minimum	Average
First	.24	.17	.2	.24	.19	.2
Second	.36	.25	.3	.35	.29	.3
Third	.54	.38	.45	.55	.4	.45
Fourth	.8	.57	.68	.8	.575	.7
Fifth	1.2	.85	1.01	1.2	.85	1.01

Fifty newly hatched larvae, taken from several different hatchings, were killed by immersion in hot water and then placed in 70 per cent alcohol. The width of the head capsules was measured under a wide-field binocular with a calibrated ocular micrometer. The average of these 50 measurements was .2 mm. Then larvae of ages from 1 day on were killed and measured in the same way until the second instar appeared. Fifty second-instar larvae were then measured, and the average of these measurements was .3 mm. By dividing .2 by .3 the factor .666$\pm$ or .67, was obtained.

Head capsules of 50 full-grown larvae were next measured. Larvae that had begun spinning their cocoons were used for this purpose, since there was no doubt of their being full grown. The maximum head capsule width was 1.2 mm., the minimum .85 mm., and the average 1.01 mm. Calculation from these figures, using the factor .67 given above, gave the theoretical maximum, minimum and average widths for five probable instars, as shown in table 2. To be certain of the number of instars, however, larvae of various sizes were killed and measured until 50 measurements falling within the calculated extremes of each instar had been recorded. No larvae were found whose measurements did not fall within the theoretical limits of one of the instars. These measurements were averaged and the averages, as well as the maximum and minimum widths, are recorded in table 2. The close agreement between the calculated and the actual measurements makes it evident that no instar has been missed and that five larval molts actually occur.

[1] Fifty larvae of each instar were measured.

Time of larval development.—Seventy larvae were reared in the individual cages, and the data relative to the length of the larval period or total of the five stadia are summarized in table 1. The prepupal stadium is included with the larval stadia, since it is not separated by a molt and is only a day or two in length.

Pupa: Appearance and development.—A day or two before pupation the fully developed larva spins a thin cocoon within a rolled leaf. The caged individuals occasionally spun up between a leaf and the side of the vial. It then begins to shorten and at the end of the prepupal period is about half its former length. After finishing the cocoon the larva is almost inactive, moving only when disturbed.

Table 3.—Number of eggs laid per day from emergence until death by fertilized females of *Platynota stultana*. Temperature 70° F.

Cage	Days After Emergence													
No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14* Total
4	0	0	0	0	51	19	22	0	0					92
5	0	0	94	0	36	56	14	7	0					207
6	0	0	115	43	25	24	0							207
10	0	0	0	9	49	35	42	20	19	10	0			184
11	0	0	188	90	47	68	38	38	19	10	0			498
12	0	0	0	143	145	68	32	39	13	7	6	3	0	456
14	0	0	155	0	144	33	14	12	19	0	0	0	0	377
15	0	0	0	154	42	0	0	0	0	45	33	0	19	0 293
16	0	140	74	63	39	0								316
17	0	0	139	58	38	0	85	42	0	33	15	0		410
18	0	0	96	43	28	23	12	9						211
19	0	0	148	40	29	21	0	27	7					272
Total	0	140	1009	643	673	347	259	194	77	105	54	3	19	0 3523

Immediately after the final larval molt the pupae are creamy white, but they soon begin to darken and finally become yellowish brown or brown. They vary considerably in size, the maximum length encountered being 9 mm. and the minimum 5 mm. The average length of 40 pupae that were measured was 6.96 mm.

The data relative to the length of the pupal stage of 73 individuals are summarized in table 1.

Adult: Emergence.—Before the adult emerges, the pupa wriggles head foremost from its cocoon, usually coming about half way out. A short time later the emerging adult splits open the anterior end of the pupal case, one short dorsal split and two converging ventral ones extending back from the front end. The adult wriggles free of the pupal cuticle and then runs about until it finds a suitable location for expanding its wings. In the cages this was usually on the side of the glass tube with the head up. The wings were held together, vertically from the body, until dry.

Appearance.—This moth is comparatively small, with long labial palpi and antennae. The fore wings are dark brown with the outer half lighter yellowish brown, this variation in color being more clearly marked in the male. In the original description Walshingham gives the alar expanse as 12 mm. Barnes & Busck in their description of this species as *P. chiquitana* (see synonymy) give this measurement as 12 to 16 mm. The moths reared in the present studies conformed with the latter measurements, the females generally being larger than the males. Detailed taxonomic descriptions are given by the aforementioned authorities.

The sexes are readily distinguished by the form of the abdomen as

viewed ventrally, that of the female being larger, more turgid, and the lobes of the ovipositor showing plainly.

Oviposition.—Egg-laying records were made of 12 mated females, four virgin females, and one female that was not mated until seven days after emergence. Table 3 shows the daily oviposition of the 12 fertilized females until death, as well as the total number of eggs deposited by each. These 12 females laid a total of 3523 eggs. Of this number 1792, or 50.86 per cent, were deposited during the first four days of adult life, and 3265, or 92.68 per cent, were laid in the first eight days. One female oviposited as late as the thirteenth day of adult life.

As shown in table 3, one moth began ovipositing the second day after emergence, seven began on the third day, three on the fourth, and one on the fifth. Ten of these females deposited more eggs on the first day of their respective oviposition periods than on any one day thereafter. The other two moths laid the largest number on the second day. The

Table 4.—Length of oviposition period and longevity of mated adults of *Platynota stultana* at 70° F.

	No. Eggs Laid per Female	Oviposition		Post-oviposition period, days	Longevity[2]	
		Preoviposition period, days	Oviposition period, days		Female, days	Male, days
Maximum	498	4	10	4	14	21
Minimum	92	1	3	0	6	6
Average	293.6	2.3	6.7	1.1	10.1	13.4

largest number of eggs laid by one female in one day was 188, and the largest individual total number of eggs laid was 498, by the same female.

The length of the oviposition period and the longevity of 12 pairs of adults are given in table 4.

Parthenogenesis.—Four newly emerged females were used to test for parthenogenesis. They were placed under the same conditions as the mated females except that no males were put in the cages. The data are summarized in table 5. Two of these females died without ovipositing, and the two that did lay eggs deposited a small number as compared with the mated females, and most of the eggs were abnormal in size and shape and were scattered about over the slide instead of in a group. These eggs were placed with the eggs from the mated females for incubation. No embryonic development occurred in any of them, and after a week or so they were dried and shriveled. Apparently the *Platynota* moth is not parthenogenic.

At the time of death the abdomens of these unmated females were turgid and of a greenish color due to the retained eggs, while those of the fertilized females were shriveled and much reduced in size.

One female, cage 7, was left as a virgin for seven days. During this time no eggs were deposited. A male was then introduced and two days later she began ovipositing. A total of 93 eggs were laid between then and her death at 19 days of age. These eggs were fertile and hatched normally. Two offspring, a male and a female, were reared to adults.

Parasites.—Of 26 larvae collected on the roses in the greenhouses at Alexandria and brought to the laboratory for rearing, five were parasitized. Four of these parasites emerged as adults; the other died as a pupa

[2] Twelve females and 10 males. In two cases one male was used with two females.

after it had left the host. These four parasites represented three species of Hymenoptera. They are as follows:

Meteorus dimidiatus (Cress.) one specimen, determined by C. F. W. Muesebeck. This parasite left the host larva during the fourth instar of the latter, spun its cocoon within the silken web of the *Platynota* larva, and emerged 10 days later. The *Platynota* larva lived for 11 days after the parasite had left its body, but it was inactive and did not feed.

Angitia ferrugineipes (Ashm.), two specimens, and *Cremastus* sp. near *similis* Cush., one specimen, all determined by R. A. Cushman. These parasites emerged from larvae in a group cage, and exact data on the instars of the hosts are not available.

It is not known at what instar of the *Platynota* the parasitization of any of these species occurred.

Table 5.—Oviposition and longevity of unmated females of *Platynota stultana* at 70° F.

Cage No.	Length of Life, Days	No. Eggs Laid	No. Eggs Hatched
8	8	0	
9	7	0	
13	16	47	0
20	13	8	0

Summary.—The tortricid moth *Platynota stultana* Wlsm., a native of Mexico and California, has been found for the first time in the eastern part of the United States as a pest of greenhouse roses.

The procedure and methods for the life-history studies of this insect are described. The studies were made at approximately 70° F. The habits and appearance of the various stages are discussed.

The mated females readily oviposit on glass slides when confined in wire-screen cages. Complete and accurate oviposition records were therefore possible. This moth is apparently not parthenogenic, since unmated females either died without ovipositing or laid abnormally shaped eggs which did not hatch.

The average number of eggs deposited per fertilized female was 293.6. The largest number of eggs laid in one day by one moth was 188.

Average lengths of the various stages are as follows: Incubation period nine days; larval period 31.1 days; pupal period nine days; from egg to adult 48.6 days. As calculated by Dyar's rule there are five instars.

Three species of hymenopterous parasites, *Meteorus dimidiatus* (Cress.), *Angitia ferrugineipes* (Ashm.), and *Cremastus* sp., were reared from *Platynota* larvae collected on greenhouse roses.

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STATUS OF THE TOMATO PIN WORM *GNORIMOSCHEMA LYCOPERSICELLA* BUSCK IN PENNSYLVANIA

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In the JOURNAL for February 1933, the writer described an outbreak of the tomato pin worm in a greenhouse near Coatesville, Chester county, Pa., and its apparent eradication by omitting the fall tomato crop and leaving the house open and unheated until the spring crop was planted the following February. No pin worms have since been found on this farm or its vicinity.

However, in September 1933 my attention was again called to the occurrence of this insect in a tomato greenhouse near Kennett Square, in Chester county, where it had been noted by the grower for about one year. A careful survey during the past year has revealed this insect scattered in greenhouses from Oxford, Chester county, on the west, to Chester, Delaware county, on the east, and from north of Unionville, Chester county, on the north, south into northern Delaware. I have not yet (1935) found it in tomato houses or adjacent plantings in the truck-crop area of northern Philadelphia county or southern Bucks county. In addition to this outbreak in southeastern Pennsylvania, another apparently unrelated appearance of tomato pin worms was found in 1931 in the vicinity of New Castle, Lawrence county, Pa.

In the Chester county area the pin worm has been found feeding on four species of solanaceous plants.

1. *Tomato.*—Here the injury may begin while the plant is still a seedling, by the larva boring into the leaves soon after hatching and making a narrow mine which soon assumes the blotch type. One grower at Kennett lost 15,000 seedlings during the past fall (1934) because of the pin worms mining into the leaves until no green surface remained. The stem may also be bored so that the plant wilts above the entrance hole. As the plants increase in size, the mines are found chiefly in the older leaves, with fewer in the new growth unless the plants are badly infested. Leaf petioles may also be mined. Later, when the tomatoes are still green, the larvae bore directly into the side of the fruit or may enter the stem end, eating holes into the interior tissues and frequently loosening the fruit so that it drops off the stem. Molds and rots entering these holes help to make these tomatoes unmarketable. Channels are also made in and on the main stems and in the flower buds. Damage to tomatoes may occur both in the greenhouse and outdoors, the latter injury appearing worst from midsummer until fall. The extent of the greenhouse injury is shown by the fact that one grower in Chester county picked only 52 baskets of marketable tomatoes from his 1934 spring crop, which normally should have produced 450 baskets. Another grower in 1935 obtained three baskets of good tomatoes from a one-sixteenth acre tomato

[1] Publication authorized by the Director of the Pennsylvania Agricultural Experiment Station, Jan. 2, 1935, as technical paper 674.

patch. In the November 1, 1934, number of the Insect Pest Survey Bulletin, R. E. Campbell noted that many California tomato fields showed practically 100 per cent infestation of fruit during the 1934 season. Shipment of infested tomatoes and of the infested seedlings helps to spread these insects.

2. *Eggplant.*—Pin worm larvae have been observed making typical blotch mines in eggplant leaves in gardens adjacent to infested tomato houses.

3. *Potato.*—Injury to potato leaves was found in several fields near heavily infested greenhouses and tomato patches. The larvae made typical mines but here they also webbed together adjacent leaves.

4. *Horse Nettle.*—This is an occasional food plant near infested greenhouses. Since this plant is widely distributed in southeastern Pennsylvania, it forms a medium for the spread of the pin worms.

Only very slight feeding was done on small tobacco leaves when no other food was available. Dry tobacco leaves were somewhat toxic. Attempts to get these larvae to feed on the leaves of chrysanthemum, calendula and sweet pea were practically unsuccessful.

Notes on biology.—Although this insect has not yet been very thoroughly studied in Pennsylvania, the following facts have been noted: The eggs, which are very small (.2 by .4 mm.), rounded oval, opaque yellowish white, with reticulated surface, are mostly laid on the lower surface of the leaves, although a few are also found on the stems and fruit. In the laboratory the egg stage lasted four to seven days. On hatching, the tiny larva, .6 to .8 mm. long, is unmarked except for a dark head and cervical shield. It soon crawls for a short distance, usually only a few millimeters, then eats a hole into the leaf surface. The larva may try several spots before it finally goes on into the leaf, and the tissues surrounding these temporary feeding holes may collapse. When it finally starts into the tissue a channel is made between the upper and lower surfaces of the leaf. This mine broadens as the larva grows, and is so transparent that the leaf-filled alimentary tract of the larva can be readily observed by light shining through the leaf. After the larva has fed until it is one-third to one-half grown it leaves the mine, emerges upon the leaf surface, and soon begins to spin a light web with which it draws together a fold or crease in the leaf. Most of these folds are made from the underside of the leaf. Within this protected area it makes a larger mine than before, frequently entirely destroying the leaf, which becomes a mere twisted shell.

When the larva has reached its full length of 6 to 8 mm. it leaves the mine and drops to the ground on a slender thread, or may make its way down the stem. Pupation may occasionally occur behind the strings holding the tomato plants, or even rarely in the leaves or fruit, but usually the larva crawls under clods or rubbish on the soil or enters it a short distance, then constructs a flimsy cocoon, within which it pupates. The pupal stage in the laboratory averaged from one and a half to two weeks. The entire life cycle was from five to six weeks.

As the larva grows it gradually develops a definite pattern on the

dorsum of the thorax and abdomen, at first brownish or light orange, but becoming dark gray blue or purplish, on a greenish blue ground color. The larva is pictured in the February 1933 JOURNAL article.

On emerging from the cocoon the moth is very similar to the moth of the potato tuber moth and the eggplant leaf miner, but smaller than either. It flies about and soon mates. During the daytime these moths rest on the plants or under the clods and rubbish, and are easily disturbed. As sunset approaches they begin to fly about and many will be found flying against the greenhouse glass, especially in the west end of the house toward the waning sunlight. These moths are quite strongly attracted to electric lights, and many have been caught on sticky fly papers suspended beside the lights. Lights hung slightly above the level of the tops of the tomato plants attracted the most moths. Clear mazda globes of 50 to 250 watts, as well as a blue globe, were attractive.

In lightly infested houses much of the injury was close to the white-painted posts supporting the greenhouse roof, as though the moths first alighted on these posts, then moved to adjacent leaves to oviposit.

Natural control.—A few hymenopterous larvae have been found feeding on pin worm larvae. During the summer of 1934 a number of adults of an ichneumonid, identified by R. A. Cushman, U. S. National Museum, as *Angitia ferrugineipes* (Ashmead), were reared from pin worm larvae collected in a tomato garden near Kennett Square, Pa. It is interesting that Swezey [1928. Proc. Hawaiian Ent. Soc. 7(1): 177] stated that about 50 per cent of the pin worm larvae collected in Hawaii were parasitized by the closely related *Angitia blackburni* (Cam.). *Microbracon juncicola* (Ashm.) and *Apanteles epinotiae* Vier. (identified by C. F. W. Meusebeck), and *Tetrastichus* sp. (identified by Gahan) have also been reared, the latter probably being secondary.

Control measures.—Based on the apparent difficulty experienced by this insect in passing our winters outdoors, and on the fact that they will not feed on our common greenhouse flowering plants, recommendations have been made to a number of growers in southeastern Pennsylvania and in the New Castle, Pa., area that they either omit the fall crop of tomatoes and substitute flower crops or that they leave the greenhouses open to the weather for some time between the end of the fall crop and the beginning of the spring crop in February. The first method is apparently the more effective. Only seedlings from guaranteed pin worm-free sources should be planted. These methods have been very effective where tried. The Humpton greenhouses, mentioned in the 1933 JOURNAL article, and many other houses have not again shown any pin worms where the fall crop was omitted. It will probably be necessary for every tomato grower in a neighborhood to follow this procedure, however. Otherwise any grower raising a fall and spring crop could carry the pin worm through the winter and his neighbors' greenhouses and gardens would become reinfested with them in the spring. The pin worm may appear to be scarce in the early part of the fall crop but it breeds so rapidly that it may build up populations sufficient to damage the spring crop badly.

Handpicking of infested leaves, beginning with the very small seed-

lings and repeated at short intervals throughout the season, has been used by a number of the growers and has helped greatly to keep down the numbers of pin worms in their greenhouses. However, the growers see and pick only those leaves showing the larger mines and thus miss many leaves, so that some larvae develop enough to pupate. This method involves considerable labor and constant vigilance to be effective and is not so applicable to outdoor plantings. The usual practice of removing the lower leaves of tomato plants undoubtedly removes a large percentage of the larvae, as these are the leaves in which most of the feeding occurs. Unfortunately, however, the growers are rather careless in disposing of these leaves, piling them up outdoors instead of otherwise destroying them at once. If the leaves lie on the aisles or outdoor soil long enough to dry out slightly, the larvae desert them and either pupate or crawl onto nearby beds or plants. Therefore the grower should be urged to gather up and destroy these detached leaves within a very short time after he removes them from the plants. Infested plants outdoors should be burned where they grew and the soil then thoroughly plowed under and cultivated.

Use of high and low temperatures.—Although no extensive experiments have been tried to determine the effects of various temperatures on the pin worms, the following observations are of interest in this connection: One heavily infested house, where the crop had been practically destroyed, was tightly closed before the removal of the plants, and left closed for a week in June. During this period the sun heated this house to such an extent that the soil temperature two inches deep in the beds went up to 109° F, the soil surface temperature was 120° F, and the temperature at five feet above the beds was 137° F. This heat brought many thousands of moths out of the beds and killed them within a short time after they began flying about. Larvae on the plants were also killed and the control in this house was made more complete by using a heavy cyanide fumigation near the end of this heating period. In other houses, where tile systems were available, the beds have been sterilized of pin worms by steaming.

Thorough cleanup, soil sterilization, and fumigation after an infested crop will do much to protect the next crop but it may not entirely eradicate these insects.

Although these insects are subtropical or tropical in origin, it might be possible for them to become acclimated gradually to our winters, and there is some indication that this has already started. In that event, omission of a crop of tomatoes during the winter might not always have the desired result of preventing reinfestation in the spring, even in isolated greenhouses. Experiments have been started to determine the effect of outdoor low temperatures. Infested leaves removed from tomato plants in a greenhouse having a constant temperature of about 60° F were placed in jars beside a thermograph outdoors from Dec. 10 to 18, 1934. During this period the air temperatures ranged from 15 to 49° F and the mean was 30.6°. Within 30 hours after these leaves had again been placed in the laboratory at 70° F many active larvae emerged from them and resumed their feeding and development.

Stomach poisons.—In California calcium arsenate has been recommended against the pin worm. Lead arsenate also has value for treating small tomato plants, and dipping the seedlings in these and other arsenical sprays has protected them for a considerable period. These poisons should always be applied so that they cover the lower side of the leaves as well as the upper. Phenothiozene, 1 pound in 50 gallons of water, was also quite toxic to pin worms on tomato plants when the plants were dipped in it.

Contact insecticides.—Experiments show that pin worm larvae are very easily affected by derris, pyrethrum, cubé and nicotine dusts and sprays, and proprietary insecticides containing these materials, or extracts of them in combination with various carriers. In contact with pyrethrum dusts the larvae rapidly become affected, regurgitate the contents of their alimentary canal, and roll and twist until well coated with the materials. There is seldom much recovery if the larvae contact these materials. Nicotine dusts cause a similar reaction. Ground derris and cubé root, of 2 to 4 per cent rotenone content, and mixtures of these with carriers such as dusting sulfur, bentonite, inert C, etc., also are toxic, although the larvae die quietly without the violent reactions and strong regurgitation characteristic of pyrethrum effects. Tomato leaves dusted with a derris powder containing 4 per cent rotenone were still quite toxic to these larvae at the end of four weeks, although the plants were exposed in a window during that time. Too high dilution with carriers, however, and some commercial materials containing extracts on carriers, were much less effective.

The above pyrethrum and derris materials have value when applied to the seedlings at the time of setting them in the house and can be substituted for arsenicals after the tomatoes form. They should be made to reach the lower surface of the leaves. Pyrethrum dusts also kill some of the moths. Dusting sulfurs alone seem to have little value against the pin worms. Nicotine-penetrol sprays killed those larvae which they contacted, but only a few of the mines were penetrated by these materials.

Fumigants.—Certain fumigants have shown rather indifferent results. Calcium cyanide fumigations at one-week intervals killed many adults but many of the moths emerged from the beds between fumigations and had time to oviposit. The eggs and the larvae within the mines were not affected at dosages which were nontoxic to the plants. Nicotine fumigations had about the same effect, and these fumigants would have to be used at frequent intervals to be very effective. Larvae exposed to burning nicotine fumigating powders were killed outside of the leaves but only a few larvae in the mines were affected.

In laboratory experiments larvae crawling on tomato plants were killed by naphthalene crystals placed in the same container. This might be used on tomato house aisles as it is used for the white fly, but should be discontinued when the fruit forms because the tomatoes absorb the odor of naphthalene. Tobacco dust or stems on the beds would kill some of the larvae dropping to the ground to pupate, but the possibility of mosaic carriage by the tobacco should be considered.

FURTHER DEVELOPMENTS CONCERNING WAX PRODUCTION BY THE HONEYBEE COLONY

I. A STUDY OF THE PRODUCTION OF WAX SCALES AND COMB BUILDING[1]

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For several years prior to the start of these experiments there had been considerable comment concerning variations in beeswax, with special reference to its impurities. An analysis of the various diversities of opinions regarding certain of these problems brought out the fact that there had not been a thorough investigation into the possible variations of our domestic beeswaxes.

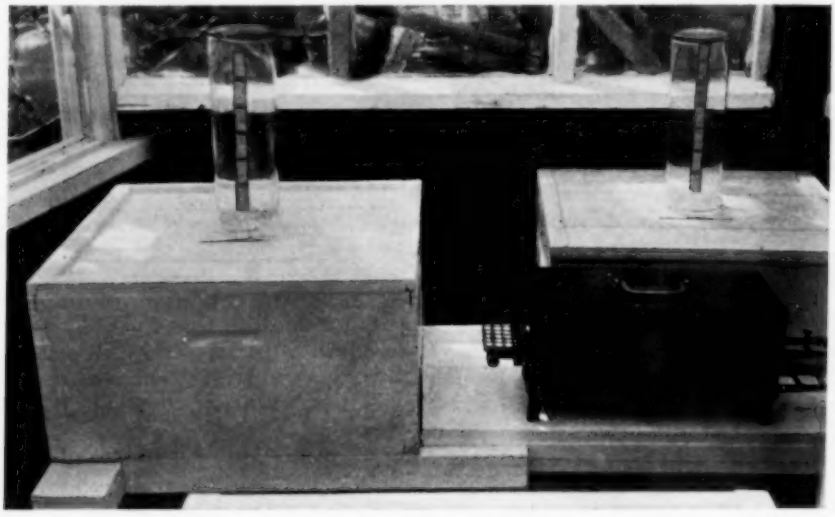

Fig. 1.—Glass-enclosed temperature-controlled compartments.

The first step, it seemed, was to determine whether any appreciable variations did occur, and if so to what they could be attributed. If certain differences did exist, then the wax produced from honeys of various floral sources or sugar syrup might give a satisfactory answer.

With such a thought in mind, various samples of honey were selected during the summer of 1930 and tests were started during that fall in the beekeeping greenhouse at the University of Wisconsin.

Procedure.—Colonies of Italian bees of about equal strength were selected from the university apiary and placed in ordinary 10-frame Dadant hives located in glass-enclosed and temperature-controlled com-

[1] Contribution from the Department of Economic Entomology, University of Wisconsin. Acknowledgment is made of the helpful suggestions made by Prof. H. F. Wilson, under whose direction this work was done.

partments, fig. 1. Later, one of these 10-frames hives was replaced by an observation hive to make it possible to observe more closely the process of wax production and comb building. Each colony was kept well within the confines of its compartment and the only food or water available was provided by the writer. All of the bees used in this phase of the experiment must have been at least one month old when placed in the compartment on November 4, because the nectar-producing plants had been killed by a frost in early September of that year.

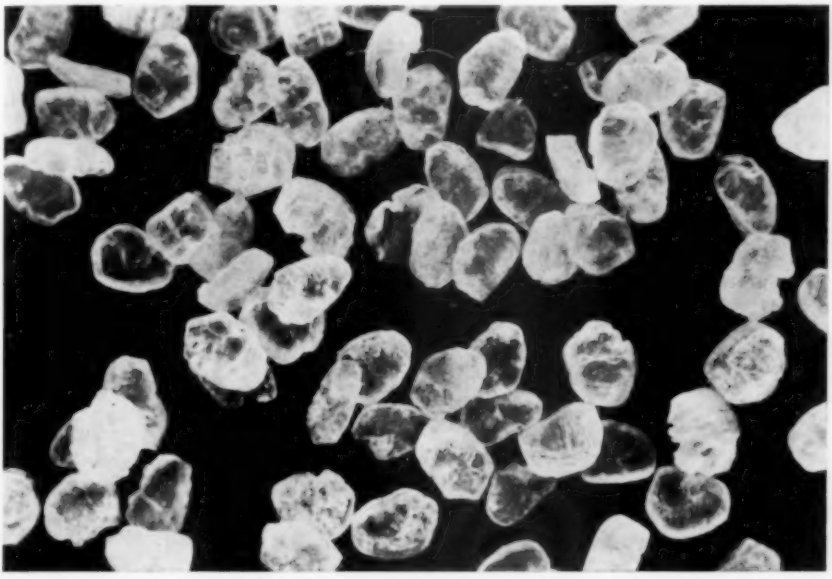

Fig. 2.—Wax scales greatly enlarged.

One colony was fed only sugar syrup, (one part of water to two parts of sugar, by weight) and water. Each one of the other colonies, with the exception of one, was fed a honey of a different floral source and water, and that colony was kept for brood-rearing as a check. The wax was removed from the experimental colonies every two weeks throughout the experiment, thus stimulating the production of wax and prohibiting the rearing of brood. In every case except the check, the colony was kept until queenless and only a few bees remained in the cluster.

On February 4, 1931, the dead colonies were replaced by colonies which had been in winter quarters for a period of two months. Therefore, these bees must have been at least four months old before the start of the second phase of the experiment.

Observations.—Because of their confinement, the colonies fed the various honeys soon became filled with feces and died in one and one-half to two and one-half months, depending upon the type of honey. The colony fed sugar syrup continued to produce wax for a period of six months and showed no noticeable accumulation of feces.

In general, the observations made by the writer concerning the secretion of the wax scales and the process of comb building conformed very closely with those made by Huber (*3*) and Castell (*1*).

It was noted that as the older wax-producing bees died, other bees from the other colonial casts were capable of making the necessary changes to carry on this work.

As has been previously reported by Gwin (*2*), it was noted that bees do not confine themselves to the wax scales they secrete during the process of comb building, but incorporate other surrounding material such

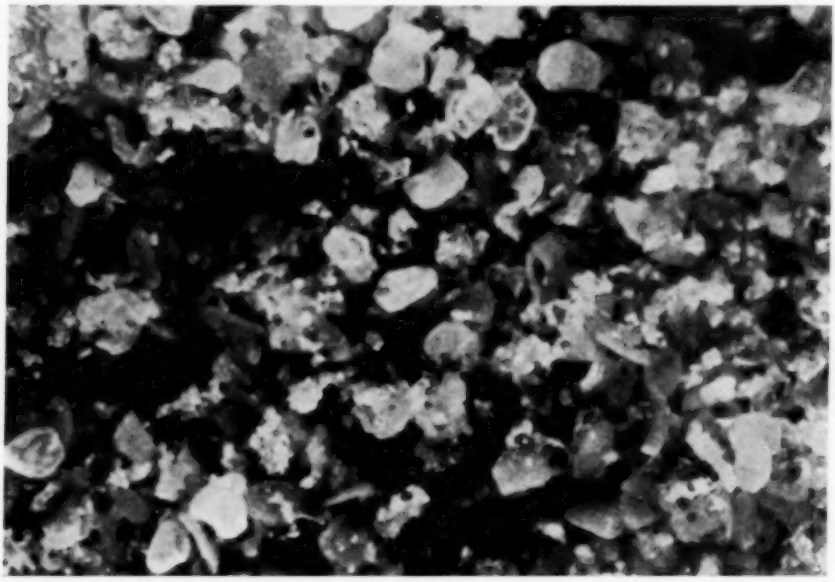

Fig. 3.—Lost scales and wax debris found in the bottom of hive after long wax production.

as other comb, propolis, wood, etc., which will be discussed in another paper.

It was further found that in the process of either normal or abnormal wax secretion the bees were not always entirely successful in their manipulation of the wax scales and lost many of them. Distinct perforations through many of these lost scales clearly indicated that they had once been fastened to the spines on the bees legs but apparently had been lost during the process of bringing them forward to the mandibles for mastication, fig. 2.

A colony which had been kept producing wax for a period of several months soon had large accumulations of these lost scales and bits of partially masticated wax which they were unable to hold during the process of comb building, fig. 3.

Closer examination of many of these wax scales revealed a certain

stratification, fig. 2, which indicated that the wax was secreted in layers and certain striations which the writer believes indicated the impressions of the fat cells of the wax glands.

Throughout the entire experiment it was noted that the wax scales of various bees varied greatly in size. This size variation in the wax scales was attributable to the location of the wax plates and the length of time the bees had been kept producing wax. The size increased with the length of the period of wax secretion. In order to determine the exact variation of these scales the following samples were selected:

(a) Medium-sized scales from an anterior pair of wax plates.
(b) Very thin scales from an anterior pair of wax plates.
(c) Very thick scales from an anterior pair of wax plates.
(d) Average-sized scales from a posterior pair of wax plates.
(e) Very large scales from a posterior pair of wax plates.

The above scales were then placed in a desiccator containing calcium chloride and after two weeks' time were weighed by means of a microbalance. Five scales were weighed at one time to alleviate error and to get an average as follows:

Sample	Weight of Five Scales, *mg.*	Average per Scale, *mg.*
a	5.254	1.0508
b	2.338	.4776
c	8.511	1.7022
d	3.306	.6612
e	6.180	1.2360

The average of all the above scales was 1.0256 mg. Therefore it would take approximately 453,258 scales to make one pound of wax if water-free wax scales were used and no loss of wax scales or bits of partially masticated wax were taken into consideration.

The wax produced by the colony fed pure sugar solution was somewhat more fragile than that produced by colonies that were fed the honeys.

Conclusion.—Colonies of bees when fed either honey or sugar syrup produced wax without being fed pollen.

These experiments prove that once a bee is capable of doing routine activities about the hive, its age is not necessarily a factor governing its ability to secrete wax.

When fed sugar syrup and water in a temperature-controlled compartment, a colony of bees was kept producing wax for a period of six months.

When used for wax production, bees persisted longer when fed sugar syrup than when fed honey, other factors remaining constant.

It was possible to rear young bees under these controlled conditions provided they were supplied sufficient pollen, honey or syrup, and water.

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SPRAY AND DUST POISONING OF HONEYBEES IN NEW JERSEY[1]

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The poisoning of honeybees by agricultural sprays is a problem which the New Jersey beekeeper has had to contend with from time to time. In the past the cases of poisoning were usually confined to certain restricted areas and could be expected at rather definite times. For example, the poisoning of bees in the orchard area was to be expected during the later part of the blooming period, while in the potato area poisoning always occurred at the time clover started to bloom. Until recently, however, the beekeepers in these localities had largely overcome these difficulties; either by agreements with the growers concerning spray practices in the orchard areas or by moving their bees to new localities outside of the potato area. Just at a time when the beekeeping industry had modified its operations to avoid this problem successfully, it seemed strange to find that in the last two years this problem had again become serious. As the reported cases of poisoning of honeybees were particularly numerous during the season of 1935 this problem has been carefully studied to determine the causes and reasons for this sudden increase by poisoning.

The majority of the reported cases of poisoning in this study were of a severe nature, where the colony had been rendered unproductive or killed outright. As these cases were usually promptly reported, the sources of poisoning, as a general thing, were easily determined. In the same general areas from which serious cases of poisoning were reported it was not uncommon to find cases of slight poisoning which the beekeeper had not reported. It is the writer's opinion that slight cases of poisoning are much more common in the southern and central portions of the state than the beekeepers realize, and that many cases of crop failure which are reported as due to failing queens or failure of the honey flow may be attributed to the gradual weakening of colonies in this manner. This type of poisoning has had much to do with the disappearance of honeybees from many of the farms in the orchard and vegetable areas.

There are several factors which partly account for the general increase of poisoning in 1935: (1) exceptional apple scab conditions during period of apple bloom, (2) use of clover as a permanent cover crop in orchards, and (3) the generally increased use of arsenical dusts against insect pests.

Another influencing factor was the extremely dry weather during the summer of 1935 which resulted in a general failure of the clover crop and in ideal conditions for the retention of poison dusts on the plants for prolonged periods. Discussion of these factors follows.

Poisoning during period of apple bloom.—The increased number of cases of poisoning of honeybees in New Jersey during the 1935 blooming period is partly accounted for by the fact that there was a decided increase in the use of honeybees for pollination purposes during the past

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

season. The fact that more beekeepers and growers were involved in this operation would tend to increase the possibility of spray poisoning to bees through some misunderstanding on the part of one or the other of the operators. While the beekeeper and the orchardist directly involved may have a complete understanding, there is no way of assuring that neighboring orchardists will not apply an early arsenical spray. Our experience in New Jersey in the past has been that the experienced growers realize this danger and as a rule do not apply their petal-fall sprays until all danger of poisoning is past.

The spring of 1935, however, was unusual in that the grower had to contend with an unusual apple scab situation during the blooming period, which called for a prompt and thorough petal-fall application. The situation was further complicated by a cool and prolonged blooming period which was favorable for a heavy scab infestation. The need to cover up for scab control as soon as possible caused many growers to apply the petal-fall spray, containing arsenic, while there was considerable bloom on the trees, which resulted in severe cases of poisoning of bees in some instances. While this particular situation is not to be expected every year, the fact that the petal-fall spray is of major importance to the New Jersey orchardist, as it is an important codling moth as well as scab spray, makes this spray a danger point. The up to the minute scab forcasts of recent years and the emphasis on proper timing and coverage of early codling moth sprays has perhaps made the grower over-conscious concerning this spray and is no doubt responsible in some degree for the early application and the resulting poisoning of honey bees by this spray.

Summer poisoning in orchard areas.—Another source of summer poisoning in the orchard areas occurs in orchards where legumes are being used as a cover crop to furnish nitrogen and organic matter. The usual procedure under this practice is to sow either alfalfa or sweet clover in alternate middles and to allow these middles to go undisturbed until the plant matures or runs out. This procedure is particularly objectionable in areas where heavy spraying for codling moth is necessary or in orchards where special arsenical sprays are applied against the Japanese beetle, especially where sweet clover is the legume used. The blooming period of sweet clover is prolonged and during the later part of this blooming period there are practically no other nectar plants available to the bees in the orchard areas. Experiments during the past year have demonstrated that bees placed in or near these heavily sprayed orchards were poisoned, with the severity of the poisoning increasing towards the end of the sweet clover bloom. The use of alfalfa as a permanent cover for alternate middles would not be as objectionable, as the honeybee under New Jersey conditions only occasionally works these blossoms.

A suggested remedy for this situation is the use of alfalfa where the orchardist wishes to keep a permanent cover crop on the middles, and the use of sweet clover where the middles are to be alternated at one or two year intervals. Under this plan the sweet clover would be cut as it comes into bloom, which would eliminate this danger of poisoning. In the opinion of the writer this procedure would not only tend to reduce greatly the numbers of honeybees visiting orchard areas but no doubt

would greatly decrease the visitations by wild bees and other insects which act as natural pollinators.

The fact that this practice has only recently gained favor with the growers probably accounts for the lack of summer orchard poisoning in the past.

Poisoning by agricultural dusts.—In 1934 and 1935 there were numerous cases of poisoning of honeybees reported throughout the southern and central part of the state during the summer months. Investigations of these cases showed that in most instances the source of poisoning was directly traceable to dusting of vegetable crops, such as potatoes, beans and tomatoes, with an arsenical dust. For example, in one severe case of poisoning where an entire apiary of 40 colonies was wiped out, the source of poisoning was a clover field adjoining a large acreage of potatoes, which was dusted with an arsenical dust after the clover came in bloom. It is perhaps fortunate for the beekeepers in these areas that there are very few weeds or vegetables which are attractive to the bees during this summer period, and that clover, which is the primary nectar producing plant, is not widely used in crop rotations or grown as hay. The increased use of dusts for controlling vegetables pests in itself constitutes a menace to the beekeeping industry in vegetable areas, as such dusts even when applied under ideal climatic conditions tend to drift on to adjoining vegetation. At the present time it is not uncommon to observe dust being applied during the middle of the day when climatic factors are far from ideal, which results in the dust being spread for considerable distances over the adjoining fields.

The increased use of airplanes in New Jersey to apply agricultural dust material is another practice which is of much concern to the New Jersey beekeeper. During the past year there was a considerable quantity of dust material applied by airplane to various agricultural crops, and while there have been no reported cases of poisoning from this source it is a situation which must be viewed with concern, as experiences in California and other states where airplane dusting has been practiced have not been happy ones for the beekeeper.

Conclusion.—The increase in arsenical poisoning of honeybees in New Jersey during recent years is due to: (1) increased use of arsenical dusts to combat insect pests, (2) the use of sweet clover as a permanent cover crop in orchards where heavy spraying for codling moth or where special Japanese beetle sprays are applied, (3) unusual apple scab situation during the blooming period, which resulted in the early application of the petal-fall spray, (4) unusually dry weather during the summer of 1935, which resulted in the failure of the clover crop and which provided ideal conditions for the retention of the dust on the plants for prolonged periods.

SEED MERCHANTS IN ARKANSAS buying from local farmers will be required to have the seed tested and tagged as to purity and germination before offering it for sale, according to a recent announcement of the Arkansas State Plant Board. Heretofore this requirement applied only to seed obtained from commercial seed men.

INJURY TO ALFALFA AND RED CLOVER BY THE POTATO LEAFHOPPER[1]

F. W. Poos, *U.S.D.A., Bureau of Entomology and Plant Quarantine,* and
H. W. Johnson, *U.S.D.A., Bureau of Plant Industry*[2]

The injury and resulting losses caused by the potato leafhopper *Empoasca fabae* (Harris)[3] to alfalfa and red clover in the eastern half of the United States apparently have been far more extensive than has been realized. The symptoms of discoloration and dwarfing of the plants produced by this leafhopper are readily recognized, but accurate figures on losses are difficult to obtain because of the numerous varying factors involved. Much of the loss incurred is from injury to young stands, which permits weeds to crowd out the alfalfa and clover. It seems probable also that these crops are frequently injured by this leafhopper during the summer, with the result that winter-killing is much more prevalent. Data are presented in this paper which indicate that in addition to a reduction in yield during a season of heavy infestation the alfalfa plants are weakened to such an extent that a reduction in yield of the first cutting, which is made before *E. fabae* becomes abundant, is obtained the following spring.

Losses to alfalfa in cages.—During 1929, experiments were started to determine losses caused by *Empoasca fabae* to alfalfa in field cages covered with tobacco cloth. Each cage covered one square rod, fig. 1, A. The tobacco cloth was placed on the frames each year in June soon after the first cutting of the alfalfa and was removed at the time of the last cutting in September. An attempt was made to maintain a heavy infestation (but no heavier than frequently occurs under natural field conditions) in one cage, while a similarly caged area nearby was kept practically free from these leafhoppers. This necessitated introducing many more *E. fabae* into the infested cages at certain times than at others because of the varying conditions of climate and host material. In 1929 only one pair of cages was used, but each year thereafter two cages were infested and two uninfested cages were used as checks.

At the regular cutting times each season the alfalfa was removed from the cages, placed in burlap bags and dried with artificial heat in a metal hay drier. The moisture content was in this way reduced to approximately 3 per cent, and yields are reported on that basis in table 1. It is noted from this table that when the year 1930 is excluded because of abnormal climatic conditions the loss in weight due to the presence of *E. fabae* ranged from 13.9 to 27 per cent. The extreme heat under the drought conditions of 1930 prevented the leafhoppers from feeding and

[1] This paper reports the results of cooperative studies conducted during 1929–34 by the Division of Cereal and Forage Insects, Bureau of Entomology and Plant Quarantine, and the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, at the Arlington Experiment Farm, Rosslyn, Va.

[2] The writers are indebted to J. W. Scrivener and Nancy H. Wheeler of the Bureau of Entomology and Plant Quarantine for much assistance with details of these experiments; also to W. H. Hosterman, Bureau of Agricultural Economics, for grading the 1929 hay samples, and to J. A. LeClerc, Bureau of Chemistry and Soils, for the chemical analyses of these samples.

[3] Order Homoptera, family Cicadellidae.

developing normally in the infested cages; therefore the usual differences in yield were not obtained during that year. This fact is of much significance, however, in indicating that the decrease in yields obtained by these tests during the other years was actually caused by *E. fabae*. It should also be stated that during 1932, when only 13.9 per cent loss in

Fig. 1.—A. Four Field Cages Covering Alfalfa Tobacco cloth removed from pair in foreground just prior to third cutting on September 4, 1931. Note injury to alfalfa in infested cage on right as compared with check cage on left. B. Effect of Infestation With *Empoasca fabae* Upon Vegetatively Propagated Plants of Russian Red Clover in 1931: 1. Uninfested. 2. Fifteen adults. 3. Thirty adults. 4. Sixty adults. 5. Uncaged plant, natural infestation. The plants were transferred from field cages to 10-inch flowerpots for photographing against a background ruled into 1-foot squares.

total yield was recorded, the yield in one check cage for the second and also for the third cutting was lower than in the leafhopper-infested cage with which it was being compared, because of the presence of the red spider on the alfalfa in this cage. It is recognized that the light, temperature and moisture conditions prevailing in cages covered with tobacco cloth are not wholly comparable to natural field conditions; however, the

consistent results obtained in these tests during four seasons would appear to have considerable significance.

The data presented in table 2 indicate that alfalfa, moderately to severely injured by *E. fabae* during one season, does not become entirely normal by the time the first cutting is made the following spring. These data, based on five pairs of cages during three seasons, indicate that the average reduction in yield was 17.6 per cent for the first cutting, which was made each year before this leafhopper became abundant in the field and before the cages were covered with tobacco cloth. The per cent loss

Table 1.—Reduction in yield caused by *Empoasca fabae* to alfalfa in cages at Arlington Experiment Farm, 1929–33.

Year	Yield on Air-dry Basis,[4] Pounds			Per Cent Loss
	Infested Cages	Uninfested Cages	Loss per Acre[7]	
1929[5]	8.13	11	459	26
1930	51.65	56.05	704	7.8
1931[6]	33.07	45.4	1973	27
1932	59.63	69.3	1547	13.9
1933	80.26	108.01	4440	25.6

for the first cutting was less than half as much during 1933 as during 1932. This is explained in part at least by the fact that conditions for alfalfa were much more favorable during the winter and spring of 1932–33 than during the same period in 1931–32. In other words the potato leafhopper-injury of alfalfa is apparently of much more importance when other factors relating to the environment of this crop are least favorable.

Table 2.—Reduction in yield of first cutting of alfalfa due to infestation with *Empoasca fabae* the previous season at Arlington Experiment Farm, 1930–33.

Year	Yield on Air-dry Basis,[4] Pounds			Per Cent Loss
	Infested Cages	Uninfested Cages	Loss per Acre[7]	
1930	11.6	16.65	808	30
1932a	16.09	22.32	997	27.9
1932b	17.73	22.32	734	20.5
1933a	30.78	34.02	518	9.5
1933b	24.40	26.81	386	8.9
Total or average	100.60	122.12	689	17.6

During 1929 the hay taken from the cages was graded by the Division of Hay, Feed and Seed, Bureau of Agricultural Economics, United States Department of Agriculture. The hay taken from the infested cage graded U. S. #2 leafy, and the uninfested cage yielded U. S. #1 alfalfa. In table 1 the loss in weight for 1929 is shown to be 26 per cent; however, the difference in price of U. S. #1 and U. S. #2 alfalfa at the Kansas City market for the years 1928 and 1929 averaged $2.10 per ton. This decrease in the grade of hay produced in the leafhopper-infested cage, as compared with the uninfested cage, thus further increased the loss caused by *E. fabae* when figured in terms of dollars and cents. .

[4] Approximately 3 per cent moisture content.
[5] Data based on one pair of cages; spring seeding, only two cuttings made.
[6] Data based on second and third cuttings only.
[7] Difference between uninfested and infested cages multiplied by 160.

After being graded, the 1929 hay samples were submitted to the Food Research Division, Bureau of Chemistry and Soils, United States Department of Agriculture, for chemical analysis. The results of these analyses, presented in table 3, indicate that the hay made from leafhopper-yellowed alfalfa from infested cages is lower in ash, protein, fat and possibly crude fiber than hay made from green alfalfa from cages kept free from leafhoppers. While it is probably not safe to base definite conclusions upon so few samples, these results are in accord with those of Willard,[8] who reported that leafhopper yellowing resulted in a decreased protein content of the leaves of the yellowed crop. Johnson[9] has also reported analyses showing that leafhopper-yellowed alfalfa leaves are high in carbohydrates and low in nitrogen as compared with green leaves.

Table 3.—Chemical composition of hay from alfalfa yellowed by *Empoasca fabae* and hay from green alfalfa at Arlington Experiment Farm, 1929.

Hay Sample From	Moisture Content	Percentage Composition (Moisture-free)			
		Ash	Protein	Fat	Fiber
	per cent				
Infested cage July 15	7.77	9.52	18.94	1.56	15.56
Uninfested cage July 15	7.36	10.2	19.19	1.74	21.34
Infested cage August 29	7.85	10.42	16.88	1.74	17.65
Uninfested cage August 29	7.09	11.81	19.31	2.48	17.06

Injury to individual alfalfa and red clover plants by various populations of *Empoasca fabae*.—The statement has often been published that the amount of injury which *E. fabae* causes to its host plants is directly proportional to the number of insects present on these plants. Since experimental data to verify this point seemed lacking in the case of forage legumes, experiments were started during 1931 to secure definite information on this point with vegetatively propagated lines of Ohio and Russian red clover and Hairy Peruvian and Kansas Common alfalfa. The tests were made in field cages, 2 feet square and $2\frac{1}{2}$ or 3 feet in height, covered with cheesecloth. Two series of four cages each were placed over individual plants of each line. On the alfalfa plants, 0, 20, 40 and 80 adult leafhoppers were placed in each series of cages. On the red clover plants, 0, 15, 30 and 60 adult leafhoppers were placed in each series of cages. All lines, except the Russian red clover, required a duplication of the number of adult leafhoppers placed in each cage in order to produce sufficiently intense symptoms of injury. In 1932 the tests were repeated, except that seedling plants of Italian red clover were substituted for the Russian clon because the plants of this line used the previous year died. During 1932 the infesting of all the red clover plants was repeated twice, making a total of 0, 45, 90 and 180 adults of *E. fabae* added to each of the two series of cages on the Italian and on the Ohio red clover. Exceedingly uniform results were obtained in the alfalfa tests during both 1931 and 1932, fig. 2, C, D. The intensity of the yellowing and amount of stunting of the plants in every instance were proportional to the number of adults

[8] **Willard, C. J.** 1932. A progress report on alfalfa leafhopper studies (Abs.). Abstracts of Papers at 25th Annual Meeting Amer. Soc. Agron., p. 13, Nov.

[9] **Johnson, Howard W.** 1934. Nature of injury to forage legumes by the potato leafhopper. Jour. Ag. Res. 49: 379–406. Illus.

of *E. fabae* that were added to the cage. In the case of the red clovers, the Ohio line was injured somewhat by the higher populations of *E. fabae*, but the resistant or repellent effect exhibited by this strain in

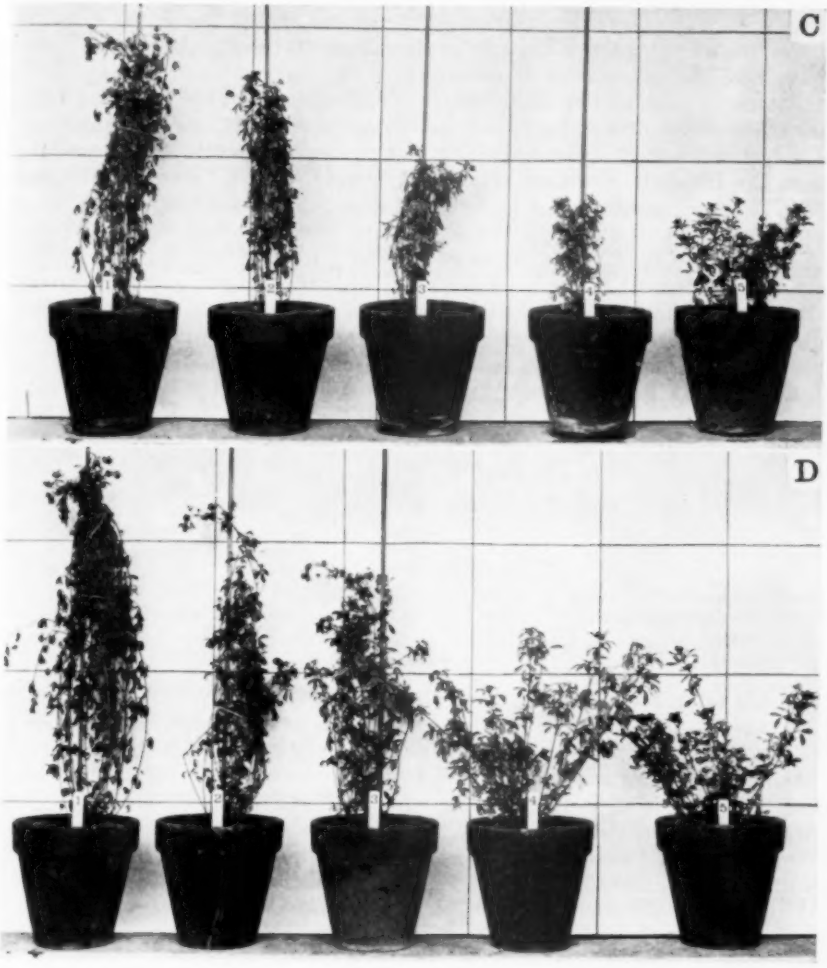

Fig. 2.—Effect of infestation with *Empoasca fabae* upon vegetatively propagated plants of Hairy Peruvian alfalfa (C) and Kansas Common alfalfa (D) in 1931. 1. Uninfested. 2. Forty adults. 3. Eighty adults. 4. One hundred sixty adults. 5. Uncaged plant, natural infestation. The plants were transferred from field cages to 10-inch flowerpots for photographing against a background ruled into 1-foot squares.

these and other tests apparently prevented the injury from being proportional to the comparatively small number of *E. fabae* placed upon these plants. The Russian red clover plants were much more injured by

populations of 60 or 30 adults of *E. fabae* than by 15 *E. fabae*, or by the natural infestation occurring in the experimental plot at the time of these tests, fig. 1, B. Striking differences in stunting were not obtained during 1932 with various populations of leafhoppers on the usually susceptible Italian variety. The discoloration of the leaves of this line in the infested cages, however, was more nearly proportional to the numbers of *E. fabae* than were the symptoms of dwarfing.

Choice of red clover varieties for oviposition.—The results of tests described in the preceding paragraph have shown that equal populations of *E. fabae* upon Russian and Ohio red clover will produce more injury upon the Russian. Previous studies by Poos & Smith[10] during 1929 and 1930, in which seedlings of Russian, Italian and French red clover were compared with seedlings of Tennessee and Michigan red clover as hosts for oviposition by *E. fabae*, showed that of a total of 523 nymphs hatching in 27 tests, 61.2 per cent hatched on the foreign, more glabrous, strains and 38.8 per cent hatched on the native, rough hairy strains. These results appeared to reveal another factor in explaining the greater susceptibility of the foreign red clovers to injury by smaller infestations of *E. fabae*. It was decided, therefore, to repeat the tests in 1933 with vegetatively propagated lines of Italian red clover and an Ohio red clover selected for vigor. The method of procedure was essentially the same as that described by Poos & Smith.[10] In three experiments a total of 60 plants were used in 15 cages. The results are tabulated as follows:

	1st Exp.	2nd Exp.	3rd Exp.	Total	Per Cent of Grand Total
Nymphs from Italian plants	590	358	583	1531	74.6
Nymphs from Ohio plants	264	112	145	521	25.4
Grand total				2052	

It will be noted from the above tabulation that only 25.4 per cent of the total nymphs hatched from the Ohio clon as compared with 74.6 per cent from the Italian clons. This represents the greatest differences ever obtained in a comparison of a resistant strain of red clover with a susceptible strain and indicates a distinct preference for the foreign, less hairy strain over the native, rough hairy strain for oviposition by this insect. This preference of the potato leafhopper for the foreign, more glabrous red clovers for oviposition is doubtless one important factor in explaining the inferior behavior of the foreign red clovers in comparative tests with American red clovers in the eastern United States, as reported by Pieters & Morgan.[11]

Summary.—Losses in yield caused by *Empoasca fabae* to alfalfa in cages at Arlington Experiment Farm ranged from 13.9 to 27 per cent during four seasons, 1929, 1931, 1932 and 1933.

Experimental data are presented to show that the amount of injury which *Empoasca fabae* causes to alfalfa and red clover is directly proportional to the numbers of this insect attacking these plants.

[10] **Poos, F. W.** and Floyd F. Smith. 1931. A comparison of oviposition and nymphal development by *Empoasca fabae* (Harris) on different host plants. Jour. Econ. Ent. **24**(2): 361–71. Illus. April.

[11] **Pieters, A. J.** and R. L. Morgan. 1932. Field tests of imported red clover seed. U.S.D.A. Circ. **210**. 24 pp., illus.

In experiments conducted with vegetatively propagated lines of red clover to test the choice for oviposition by *Empoasca fabae*, 74.6 per cent of the total (2052) numphs hatched from the foreign, more glabrous, Italian lines while 25.4 per cent hatched from a native rough-hairy Ohio line selected for vigor.

DUSTS FOR CONTROL OF FLIES ON CATTLE

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Sixteen dusts and one spray were tested outdoors against cattle flies in 1933. In 1934 the four most promising dusts, consisting of pyrethrum and derris mixtures, were tested further with all showing a high rate of efficiency. Laboratory tests in an olfactometer to supplement the outdoor tests disclose the fact that the effectiveness of the dusts is largely due to actual lethal qualities.

In the latter part of the summer of 1933 work was begun under a fellowship furnished by McCormick & Company, Baltimore, for the evaluation of dusts for use in controlling flies injuring cattle. Sixteen dust mixtures and one standard spray material were used in the preliminary tests to determine the comparative efficiency of the materials. These materials were pyrethrum and derris, directly mixed at various percentages with inert carriers and impregnated inert carriers, some with added pine oil, in several strengths. During the course of this work the spray, due to the report of deleterious effects on the cattle, and all but four of the dusts, on the basis of comparative efficiency, were eliminated.

The work was done on selected cattle in the field, with a pump type of gun. The efficiency of each material was determined on the basis of observations at half-hour intervals up to three and one-half hours, the total number of flies being counted before dusting and at each interval after the dusting. Abbot's method of determining the efficiency, based upon a supposed repellency, was used. The four highest-rating dusts were continued as a basis for the subsequent tests. Pearson's method of the selection of cattle groups and Abbott's formula took into account the factors of susceptibility of the cattle and the fluctuation of the fly population during the experiment. The influence of atmospheric conditions was evaluated by the selection of one material as a standard, this being straight pyrethrum dust, as the basis for the calculation of the effectiveness under varying atmospheric conditions. Replications of the selected material gave a sound basis for averages. The valuation of atmospheric conditions should be stressed because of the wide range of valuation of the materials under different conditions.

In the preliminary experiments each material was plotted with the other materials in its group against straight pyrethrum, which served as the standard, using Abbott's formula as the basis of calculation of percentage efficiency. In the final evaluation of the data the mean percentage efficiency of the standard was determined. The deviation of the standard from the mean gave the correction factor for placing all the materials on common ground in regard to the variable introduced by

atmospheric conditions. In the subsequent tests of the four most promising dusts the standard was discarded and replication was depended upon to give an accurate estimate of efficiency.

The four most efficient dusts of 1933 were ground pyrethrum, Black Arrow 5000 (.054 pyrethrins), 50 per cent pyrethrum and 50 per cent Treni dust, and the same plus 10 per cent Middol (pine oil).

The rating of the four materials is as follows:

1. Black Arrow 5000—90.8 per cent, based on 87 observations, 13 dustings, 1348 flies.

2. Fifty per cent pyrethrum, 50 per cent Treni dust—88.8 per cent, based on 63 observations, 9 dustings, 2182 flies.

3. Ground pyrethrum—88 per cent, based on 219 observations, 45 dustings, 4899 flies.

4. Fifty per cent pyrethrum, 50 per cent Treni dust with 10 per cent pine oil added—86 per cent, based on 63 observations, 9 dustings, 1611 flies.

The spray consisting of McCormick's concentrate, diluted with nine parts of a mixture of 50 per cent Deo base and 50 per cent Sonnenborn's #50 oil, which was rated 88 per cent on the basis of 42 observations, 7 sprayings, 1184 flies, was discarded because of the reported injury by sprays. This point will be discussed later.

In the 1934 tests, Black Arrow 5000 (.054 pyrethrins); 60 per cent pyrethrum, 40 per cent Treni dust; Black Arrow 6000; 75 per cent clay, 25 per cent derris (1 per cent actual derris) with pigment stabilizer 15 per cent added; Black Arrow 5000 (as above) with 15 per cent pigment added; Black Arrow 6000 with 8 per cent Yarmor pine oil added; and stabilized Black Arrow 5000 with 8 per cent Yarmor added were used. The dusting was done with a rotary duster in a chute covered with burlap. Field counts of the proportion of various flies showed:

Field Counts		Barn Counts	
Stable flies	12 per cent	Stable flies	70 per cent
Horn flies	70	House flies	15
Tabanid flies	15	Horn flies	10
House flies	2	Tabanid flies	4
Other flies	1	Other flies	1

Tabanid flies are disregarded in the computations. The averages are based on replications:

Field Experiments

1. Stabilized Black Arrow 5000—95.5 per cent, 126 observations, 18 dustings, 1147 flies.

2. Stabilized Black Arrow and pine oil—95.3 per cent, 63 observations, 9 dustings, 436 flies.

3. Stabilized Black Arrow 6000—90.8 per cent, 126 observations, 18 dustings, 891 flies.

4. Stabilized Black Arrow 6000 and pine oil—85.5 per cent, 63 observations, 9 dustings, 413 flies.

Barn Experiments

1. Stabilized Black Arrow 5000—92.8 per cent, 63 observations, 9 dustings, 1778 flies.

2. Stabilized Black Arrow 5000 and pine oil—91 per cent, 126 observations, 18 dustings, 757 flies.

3. Stabilized Black Arrow 6000—90.9 per cent, 63 observations, 9 dustings, 1672 flies.

4. Stabilized Black Arrow 6000 and pine oil—84.7 per cent, 126 observations, 18 dustings, 765 flies.

Direct comparisons of stabilized and unstabilized Black Arrow 5000 gave no significant increase in rating due to the presence of the pigment.

Tests to determine the effect of high humidity, using the same stabilized and nonstabilized dusts demonstrated that under conditions of high humidity there is an increase in effectiveness in each material ranging from 4.5 to 7 per cent.

The use of pine oil appreciably reduces the coverage of dusts as shown by the following:

	Cows Dusted per Pound
Stabilized Black Arrow	11
Black Arrow 5000	11
Stabilized Black Arrow 6000	9
Stabilized Black Arrow 5000 and pine oil	8
Stabilized Black Arrow 6000 and pine oil	6

Injury to cattle.—Due to the reported increase in temperature of sprayed cattle, temperature records were kept of 29 cows over a period of six days, during which the outside temperature recorded at the time of taking the cows' temperatures ranged between 62 and 70° F. These records showed a range of variability from .3 to 1.3°, with a mean variation of .7° F. It would seem, therefore, that normal cows vary considerably in temperature range and therefore such variation should not be used as a criterion of the deleterious effect of sprays.

Laboratory study to determine action of pyrethrum and derris against stable fly and house fly.—From observations in the field the authors believe that the pyrethrum and derris dusts functioned as repellents. Steps were taken to set up apparatus to measure the repellent action of these materials. McIndoo wrote that there were two conceptions of the function of a repellent: (1) that it functioned passively, masking an attractive odor of the object being protected; (2) that it functioned actively emitting odors or vapors which are disagreeable to the attacking insects. He wrote further that many substances used as repellents emit poisonous exhalations and that it is questionable whether in these cases it is primarily through the action of the olfactory sense that the insects are driven away. In other words, we do not know whether the repellent effect is caused by the stimulation of the smelling organs by the exhalations or whether the insects are injured by the passage of the exhalations into the breathing pores. He listed as poisonous repellents, coal-oil tar and petroleum and many of their derivatives, such as naphthalene, carbolic acid and kerosene. It is significant that the sprays generally found to be most effective contain one or more of the above materials.

In order to determine the repellent action of the dusts, an olfactometer was constructed. This was essentially a cross-shaped box, in which the two long arms of the cross were capped with cone traps in which the cloth screens forming the cones were removable. One of the short arms of the cross was employed for the insertion of an exhaust fan to draw air through each of the cones covered by the cloth screens. The other short arm of the cross was provided with an air-tight door through which could be introduced a full cage of flies. The repellent dust was then applied to the outer surface of one of the cones, and the other cone was

allowed to go untreated. Lights of equal intensity were placed at the end of each trap of the olfactometer.

The width of the opening of the peak of the cone was adjusted at one-quarter inch. It was found that 50 per cent of the flies would pass through an aperture of this size in five minutes. This width was desirable because observations in the field indicated that the stable flies remained upon the cows and completed feeding in three to seven minutes time. The fan was then started and the flies were introduced. There was no indication of repellent action as there was equal distribution of flies in each end of the cross. The conditions of the experiment were not satisfactory because of the highly toxic action of the dust. The numbers passing through the screen in a definite period of time had no significance because the dust particles carried by the stream of air passing from the dusted screen paralyzed and knocked down over 50 per cent of the flies before they ever reached the screen.

The procedure was then altered to meet this situation. The exhaust fan was not employed and the check trap was no longer necessary. It was found that the average time required for 50 per cent of a group of flies to pass through a derris or pyrethrum-dusted screen remained at five minutes, the same time required for them to pass through an untreated screen. In the case of the pine oil combinations, the average time required to negotiate the screens rose to an average of eight minutes, indicating that the pyrethrum and derris dust combinations had no measurable repellent action when the flies were activated by the phototropic response; whereas the pine oil combination had but a slight repellent effect. How then do the dusts function to protect cattle?

Apparently the efficiency of the dusts is intimately related to their toxicity. The toxicity of these materials was calculated in the following manner: The flies to be used in the experiment were introduced into the apparatus and the time recorded. The flies were observed in the traps and the time was recorded in seconds at which they became paralyzed. This experiment was conducted for each of the four dusts under test. Each of these tests was then replicated nine times. The results of these tests are presented in the following table:

Test No.[1]	Stomoxys Toxic Time in Seconds				Musca Toxic Time in Seconds			
	A[2]	*B*	*C*	*D*	*A*	*B*	*C*	*D*
1	463	157	360	211	1067	331	1191	391
2	356	200	323	261	1313	431	1023	324
3	586	150	495	202	1648	402	1345	366
4	532	187	482	307	1741	428	1736	348
5	415	191	411	230	1929	542	1334	296
6	460	219	501	251	1873	501	1174	380
7	525	201	420	320	1710	503	1582	371
8	500	208	363	198	2055	463	1264	284
9	365	194	451	216	2086	416	1422	394
10	440	164	432	220	1915	478	1272	408
Total Time	4652	1871	4238	2716	17337	4495	13353	3562
Average	465.2	187.1	423.8	271.6	1733.7	449.5	1335.3	356.2

[1] A test consisted of the average mortality time recorded in seconds of 100 5-day-old flies introduced into the apparatus in units of 10.

[2] *A*, Stabilized Black Arrow 6000, derris.
B, Stabilized Black Arrow 5000, pyrethrum.
C, Stabilized Black Arrow, derris and pine oil.
D, Stabilized Black Arrow 5000, pyrethrum and pine oil.

Summary from laboratory tests.—Pyrethrum and derris dusts have little or no repellent action against the house fly and stable fly under conditions of forceful tropism.

The protection given cattle by pyrethrum and derris dusts is secured through the toxic action of the materials.

The stable fly is more susceptible to toxic action of pyrethrum and derris dusts than is the house fly.

The action of the pine oil is such that it prolongs the time required for the fly to acquire a toxic dose of the material and thus increases the toxicity time and lowers the rating of the dust.

There is evidence that pine oil increases the toxic action of the derris dusts, which have a relatively low initial toxic rating.

Conclusions.—Results on dusting or spraying experiments should be calculated on the basis of the average performance of a standard material in order that the effect of climatological variables may be evaluated.

Impregnated dusts are generally superior to mixed dusts in the same series.

Stabilization does not significantly increase the value of the dusts.

Pyrethrum-impregnated dusts provide more protection per unit cost than do the derris-impregnated dusts, but the derris-impregnated dusts are more toxic per unit than are the pyrethrum-impregnated dusts.

Impregnated dusts gave better protection than the spray.

Pine oils add little to the efficiency of the impregnated dusts. They increase the initial toxicity rating of the materials but lower their efficiency over a three and one-half hour period.

FURTHER STUDIES OF ONION VARIETIES AND ONION THRIPS[1]

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Preliminary field experiments (*1*) demonstrated definite differences in the susceptibility of onion varieties to attack and injury by the onion thrips. Sweet Spanish onion plants have the lowest thrips populations of all the varieties tested. The practical value of these findings to growers warranted a more detailed study of the factors involved. Experiments have been conducted, dealing with the tolerance of onion varieties to thrips injury, the effects of some plant growth characteristics, the stage of maturity in relation to numbers of thrips and the importance of the factors of host selection. The present paper reports some of the results obtained.

Onion thrips feed on a wide range of host plants. This species has a high degree of trophic plasticity and should be able to adapt itself comparatively quickly to differences between onion varieties. In this connection it is interesting to note the continued low populations of thrips found on several sweet Spanish varieties of onions for the last four years. The data presented in table 1 are the average numbers of thrips per

[1] *Thrips tabaci* Lind.

plant for the season and the varietal classification indicated. These counts represent the average numbers of thrips on at least 20 onion plants counted four times each season for each of 28 varieties. These results are not construed to mean that the onion thrips will not become adapted to sweet Spanish varieties of onions. It will be of interest to observe whether or not the thrips population will be relatively higher if these varieties are planted exclusively over a wide area and a considerable period of time.

The question of whether or not onion thrips could live on sweet Spanish varieties of onion was tested by placing two female adults in small cages attached to leaves of the growing plants. Thrips were similarly confined on yellow globe onions, a variety susceptible to injury. The experiment was repeated several times. There were no marked differences in oviposition on the resistant and susceptible varieties. An average of nine thrips on the sweet Spanish variety and 11 on the yellow globe were found in a single cage. The thrips developed normally and

Table 1.—Comparative thrips populations for four seasons on onion varieties.

	Average Numbers of Thrips per Plant			
	1932	*1933*	*1934*	*1935*
Sweet Spanish	35	32	11	22
All varieties	118	151	74	109
Susceptible varieties	153	197	112	131

became adults at the same time on both varieties. Injury to the leaves was about equally severe but injured areas on the foliage of the sweet Spanish variety sloughed off leaving newly formed, normal tissue underneath while the leaves of the yellow globe plants turned grayish white and died where feeding had occurred.

It has been pointed out by other workers (*2*) that the angle of contact between onion leaves, particularly in the crown of the plant, has a direct bearing upon the resultant population of thrips. The leaves of plants of the sweet Spanish variety were tied together when the plants were about 16–18 inches high. They were left in this condition for five weeks. At the end of that time thrips were most numerous in the onion plantings, and a count of all the plants showed an average of 41 thrips per plant where the leaves were tied as compared to 22 thrips per plant on adjacent normal plants of the same variety. A planting of yellow globe onions six feet from this experiment had an average of 208 thrips per plant. The difference in the numbers of thrips on tied plants as compared with the untied is highly significant and indicates that the habit of growth of an onion variety has a direct bearing on the numbers of thrips which occur on that variety. Since injury was not noticeable even on the tied plants and the numbers of thrips were much lower than on the yellow globe variety, it seems apparent that the angle of contact of onion leaves is not entirely responsible for the low numbers of thrips found on sweet Spanish onions.

There is a difference of at least a month between the time of maturity of yellow globe and sweet Spanish varieties of onions as grown on muckland in Orange county, N. Y. The stage of maturity of an onion plant

might conceivably influence the relative populations which occur on that plant at any given time. To test this point sweet Spanish onions were transplanted from the greenhouse so as to coincide in time of maturity with yellow globe onions planted as seed. The seed of sweet Spanish onions were also planted on the same date but did not mature until a month later. Counts of the numbers of thrips were made just before the yellow globe plants matured, with the results shown in table 2.

The results indicate that the sweet Spanish onion plants which were

Table 2.—Comparative thrips populations of Sweet Spanish and Yellow Globe onions maturing at the same time.

Variety and Manner of Planting	Average Numbers of Thrips per Plant	Date of Harvest
Utah sweet Spanish (seed)	35	Sept. 15
Utah sweet Spanish (transplanted)	76	Aug. 10
Yellow globe (seed)	179	Aug. 8
Significant Difference	17.9	

further advanced in growth were infested with larger numbers of thrips than the plants originating from seed. Apparently the stage of development of an onion plant does influence the numbers of thrips which occur on that plant. However, the difference in populations of thrips on the yellow globe variety as compared with the transplanted sweet Spanish onions shows that the stage of growth alone does not entirely explain the reduced numbers of thrips.

Growers of bunching, or green onions, frequently experience difficulty in producing plants with tops relatively free from thrips injury. Experiments were conducted to determine the comparative merits of several

Table 3.—Results of experiments with common varieties of bunching onions.

Variety	Average Numbers of Thrips per Plant		Foliage Injury
	1934	*1935*	
White bunching	101	46	severe
White Welsh	91	40	severe
Utah sweet Spanish	27	7	slight
Japanese bunching	14	6	slight
Significant Difference	19.78	6.6	

commerical varieties of bunching onions. These experiments also afforded an opportunity to compare thrips populations on young onion plants early in the season before the maximum numbers of thrips occurred.

The results presented in table 3 show very definite differences in the numbers of thrips found on the onion varieties. The sweet Spanish and the Japanese bunching onions showed no commerical damage to the foliage, whereas the other varieties were definitely injured so far as market quality was concerned. The factors involved in low thrips populations on onion varieties very evidently operate in the early, as well as the late stages of growth of the plants.

The part which insect selection of a host plays in the resultant population on the host is generally recognized. Two experiments were conducted to obtain information as to the influence of host selection on varietal

differences of onion thrips populations. In the first of these experiments, one-half pound of sweet Spanish onion seed was mixed with one pound of yellow globe seed and drilled in rows 360 feet long and 14 inches apart. At the time of maximum thrips abundance population counts were made on plants of both varieties. The results, table 4, prove beyond doubt that the thrips were notably more numerous on the more susceptible variety. Additional observations and counts made after the yellow globe plants had died proved that no substantial increase in numbers of thrips on the sweet Spanish plants had occurred.

Table 4.—Comparative numbers of thrips on resistant and susceptible varieties of onion in mixed planting.

	Utah Sweet Spanish	Yellow Globe
	79[2]	286
	65	288
	66	276
	42	261
	57	199
	54	214
	38	194
Average numbers of thrips per plant	57	245
Significant Difference	25.742 thrips per plant	

Table 5.—Comparative number of thrips in large blocks of sweet Spanish and yellow globe onion varieties.

	Average Numbers of Thrips per Plant	
	Utah Sweet Spanish	Yellow Globe
	26	173
	36	159
	25	152
	36	197
	44	189
General average	33	174
Significant Difference	12.456 thrips per plant	

In the second experiment dealing with host selection a large block of sweet Spanish onions was grown adjacent to a large block of the yellow globe variety. At the time of maximum thrips abundance all the insects on 50 plants of the sweet Spanish variety and 50 plants of the yellow globe variety were counted. The results, table 5, demonstrate clearly that there were less than one-fifth as many thrips on the sweet Spanish variety as there were on the yellow globe onions. There was no increase in the numbers of thrips on the sweet Spanish variety after the earlier maturing onions had died although the population on the weeds adjacent to the field did increase. It seems evident that the insects avoid the sweet Spanish varieties.

Summary.—In four years of field experiments sweet Spanish onion plants have been infested with significantly fewer onion thrips than any other variety tested. From the data here presented it is most logical to assume that no single factor can be established as the sole reason for the differences in numbers of thrips found. Avoidance on the part of the thrips, angle of contact of the plant leaves, stage of growth of the plants and recovery of the plant tissues from injury all have some bearing on the problem but there are probably other influences also involved. In most instances it is likely that no single term will adequately define all the characteristics of a plant variety which influence its susceptibility to insect attack and injury.

It should be pointed out that some thrips have always been found on the sweet Spanish variety of onions and that under conditions of forced feeding they can and do develop normally on this variety. Observations of the relationships of these insects to sweet Spanish onion plants over

[2] Average of five plants.

a period of several years should provide data of both scientific and practical value.

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EXPERIMENTAL STUDIES OF THE HAIRY CHINCH BUG[1]

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Unusually heavy infestations of chinch bugs in lawns and golf courses occurred on Long Island during the years 1932 to 1935. During 1934, infestations were reported from Cleveland, Ohio, and from Philadelphia, Pa. Specimens from the above localities proved to be *Blissus hirtus* Montandon, the same species as the chinch bug infesting turf on Long Island. Previous reports of chinch bug infestations in turf grass have come from Massachusetts, Connecticut, New York and Florida. During 1935, reports of infestations were received from Maine, Massachusetts, Connecticut, Rhode Island, Ohio, Pennsylvania and Virginia. Localities in New York state from which specimens of *B. hirtus* infesting turf grass have been received are: Gainesville, Ithaca, Hamilton, Saranac Lake, Peekskill and Nyack, together with numerous localities distributed over Long Island, fig. 1. There are, no doubt, other areas in which the insect occurs but from which specimens have not been received.

Fig. 1.—Map of New York state showing distribution of *Blissus hirtus* Montadon.

The earliest symptom of chinch bug feeding has been a browning of the grass, usually in spots, which closely resembled drouth injury or sun scald. Chinch bug injury has also frequently been mistaken for brown-patch disease or sod webworm injury. Heavy infestations have resulted

[1] *Blissus hirtus* Montandon. Identification through the courtesy of Mr. H. G. Barber, Bureau of Entomology and Plant Quarantine, Washington, D. C.

in a complete killing of the grass, leaving any clover, if present, unharmed. The death of the grass has been followed by a growth of clover, weeds or some other less desirable plant such as crab grass, which usually replaced the original turf and often served as a host for the chinch bugs during the late summer and fall. Damage has appeared first in high, dry or sandy locations where a moisture deficiency probably rendered the grass less tolerant of injury by the insects. Damage to lawns most frequently occurred in areas exposed to direct sunlight and protected on the north by hedges or buildings. Damage occurred only infrequently in shaded areas of lawns. Areas of turf surrounded by gravel drives or pavement also appeared to be favorite locations. Occassional slight damage was observed on golf greens whereas approaches and areas immediately surrounding the greens were commonly injured severely. Golf courses and sod nurseries have suffered most severe damage in the region of Glen Cove, Long Island. Chinch bug injury has been especially severe in turf which contained large proportions of bent grasses. A favorite food plant has been seaside creeping bent, a variety of grass which is stoloniferous in growth habit and is widely used for northern lawn and putting green surfaces. When maintained at lawn length, a thick mat of stolons formed which afforded ideal conditions for chinch bugs. When topdressed and maintained at green length, however, creeping bent grass was relatively immune to attack.

Species of grass commonly used in the north for fine turf are chiefly the rye grasses (*Lolium* sp.), the bluegrasses (*Poa* sp.), the fescues (*Festuca* sp.) and the bent grasses (*Agrostis* sp.). There are four species of bent grass, including several varieties and many strains, which are commonly used for fine turf. Experiments to determine varietal suceptibility of grasses to chinch bug injury have been conducted for one season and the results thus far obtained indicate that there are definite differences between varieties.

Observations of the relative abundance of the various nymphal stages and adults throughout the seasons of 1934 and 1935 showed that two distinct generations occurred each year on Long Island, fig. 2. Chinch bugs reared in the laboratory from eggs to adults passed through five nymphal instars. Adults of the long-winged and short-winged forms occurred in varying proportions ranging from 4 to 72 per cent long-winged individuals at various times and in different localities. A comparison of the development in the field of the first and second broods for both 1934 and 1935 showed that during the latter season hatching of the first brood nymphs began about one week later and the development of both broods was subsequently delayed throughout the entire season. Spring rains in 1935 had no perceptible effect on the abundance of the insects. Chinch bugs were more numerous and damage resulting from feeding activities of the second brood was more severe on Long Island in 1935 than during the previous season.

As the chinch bugs reached maturity there was usually some migration into uninfested areas, although the insects quickly deserted an area at any time in the season if the grass was destroyed. Some of the adults usually hibernated in infested turf, provided sufficient undamaged grass

remained to furnish food and shelter. Adults have been seen, nevertheless, apparently preparing to overwinter in tall grass near the edges of lawns and putting greens.

During the first part of June, 1934, a fungus was found to be prevalent on the dead bodies of overwintered adults. The fungus occurred to a less extent in the fall of 1934 and throughout the 1935 season. The fungus

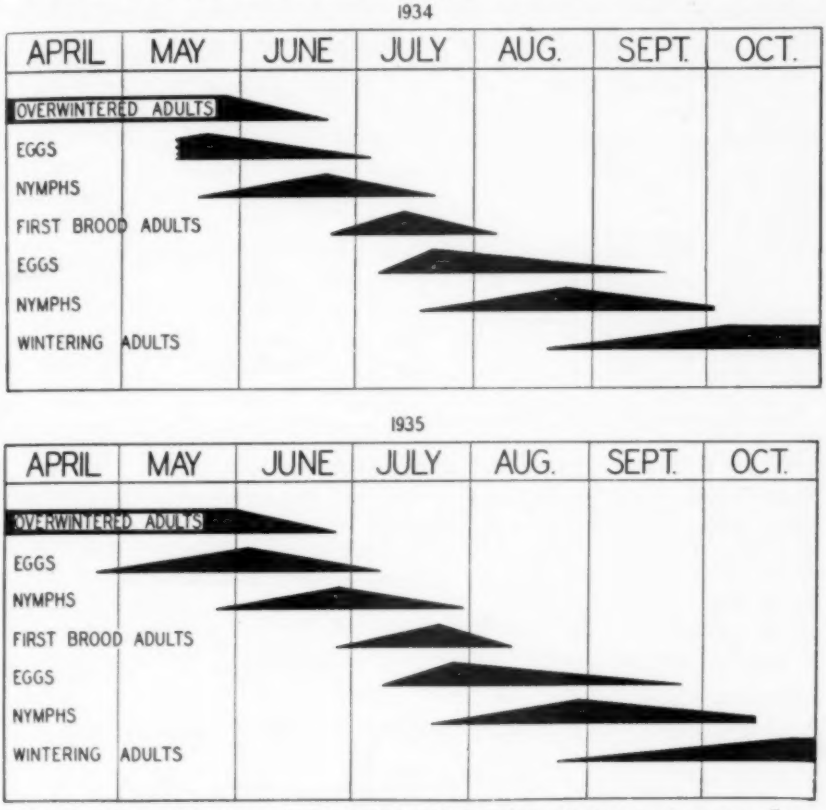

Fig. 2.—Seasonal history of *Blissus hirtus* Montadon infesting turf grass on Long Island.

was seldom seen on nymphs and eggs. Cultures of the fungus made from dead adults showed *Sporotrichum globuliferum*[2] to be present. Disease, however, has caused no perceptible reduction of infestations even though moisture and temperature conditions in lawns and golf courses are apparently favorable for fungus growth.

For testing the effectiveness of insecticides, areas of turf 16 square feet or more in size were treated in preliminary experiments. Spray materials were applied with a hand sprayer, and dust materials were ap-

[2] Identification through the courtesy of Dr. Vera K. Charles, Bureau of Plant Industry, Washington, D. C.

plied, for the most part, by hand. Applications of dusts to larger areas than could be conveniently covered by hand were made with a lime distributor which could be adjusted to regulate the rate of application. The effectiveness of the treatments was determined by recording the relative numbers of insects dead or alive at various times following applications of the treatments. From 100 to 400 insects were counted in areas selected at random in each treatment. Reliable data could not be obtained in less

Table 1.—Some materials used in chinch bug experiments which resulted in injury to lawn grasses.

Material	Rate per 1000 sq. ft.
Sprays	*Gals.*
Nicotine sulfate 1–200, potassium oleate soap 1–100	170
Nicotine sulfate 1–400, lime 5 lbs. per 100 gals.	170
Fish-oil soap 4–100	170
Lethane 420 1–400	170
Palustrex sulfonate 2–100	100
Calcium cyanide 1 lb. per 100 gals.	100
Naphthalene paste 4 lbs. per 100 gals.	170
Dusts	*Pounds*
Tobacco dust (¾% nicotine), dry	50
3% nicotine-lime	25
1% nicotine-bentonite-sulfur	25
Calcium cyanide	8
Paradichlorobenzene	8
50% naphthalene-lime	25
Chinchacide	50

than two or three days following the applications due to the fact that some materials resulted in a delayed toxic effect and others apparently produced an initial high toxicity followed later by recovery. Some of the insecticides which were tested and were unsatisfactory because of injury to the grass are listed in table 1. Among 41 spray and dust materials used in various mixtures and dilutions, the most effective spray material which

Table 2.—Results of some experiments in 1934 for the control of chinch bugs in turf.

Material	Strength	Rate per 1000 sq. ft.	Number of Tests	Total Insects Counted	Average Mortality *percentage*
Tobacco dust	¾% nicotine	25 lbs.	4	350	61.5
Rotenone dust	1%	25 lbs.	4	350	65
Nicotine sulfate-potassium oleate soap	1–400 1–100	170 gals.	6	1000	69.5
Nicotine sulfate-potassium oleate soap	1–200 1–100	170 gals.	3	700	92

was safe to use appeared to be nicotine sulfate at the rate of one part to 400 parts of water with potassium oleate soap at 1 pound to 100 gallons of spray, table 2. Higher kills were obtained from the use of nicotine sulfate at 1–200 but this mixture injured the grass. The most satisfactory dry materials from the standpoint of cost, effectiveness and safety were rotenone and tobacco dust. The one half per cent and one per cent rotenone dusts used were commercial preparations. The tobacco dusts were specified as follows:

1.—Three-fourths per cent nicotine content tobacco dust; all to pass through a 60-mesh sieve, 80 per cent to pass through a 100-mesh sieve.

2.—One per cent nicotine content tobacco dust; all to pass through a 70-mesh sieve, 75 per cent to pass through a 100-mesh sieve.

Applications of dry materials in the 1935 tests were followed by sprinkling with water, table 3. This method served to carry the material down into the turf as well as to wash the chemicals off the tops of the grass and thus minimize the danger of injury. Injury to grass occasionally resulted from the use of tobacco dust when not followed by water. The tobacco dust containing 1 per cent nicotine gave higher kills than that containing three-fourths per cent nicotine and gave results nearly equivalent to the nicotine sulfate spray at 1–400. The 1 per cent rotenone dust, however, did not prove superior to the one-half per cent rotenone dust in these tests. The nicotine-lime dusts, although highly toxic, have caused some injury to lawn grasses.

Table 3.—Results of some experiments in 1935 for the control of chinch bugs in turf.

Material	Strength *percentage*	Rate per 1000 sq. ft.	Number of Tests	Total Insects Counted	Average Mortality *percentage*
Tobacco dust	1 (nicotine)	25 lbs.	7	1100	70.6
Rotenone dust	½	25 lbs.	6	1000	70.2
Rotenone dust	1	25 lbs.	9	1150	61
Nicotine-lime	3	dusted	6	800	79.4

The hairy chinch bug is widespread throughout the northeastern part of the country and injury to fine lawn grasses constitutes a serious loss. There are two broods of the insect annually on Long Island. Short cutting, frequent watering and topdressing have apparently aided grass in withstanding injury by the insect. There are indications that different species of grass vary in their susceptibility to injury, but additional work is needed to confirm these differences. Tobacco and rotenone dusts, together with nicotine-soap sprays, seem to offer the most promising possibilities of control.

VALUE OF LIME AND ALUMINUM SULFATE AS A REPELLENT SPRAY FOR JAPANESE BEETLE

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For several years hydrated lime has been recommended as a repellent spray in the control of the Japanese beetle *Popillia japonica* Newm.[1] This material is cheap, nontoxic to human beings, and can be applied without danger to foliage. It is, moreover, equally as repellent to the beetle as lead arsenate, provided a conspicuous residue is maintained on the foliage. In the past, however, the chief objection to the employment

[1] **Fleming, W. E.,** F. W. Metzger and M. R. Osburn. 1934. Protection of orchard and shade trees and ornamental shrubs from injury by the Japanese beetle. U.S.D.A. Circ. 317. 8 pp., illus.

of hydrated lime has been the fact that it is readily removed by rain, thus necessitating frequent applications in order to insure the desired protection from the beetle.

Extensive tests have been conducted to improve the adhesiveness of hydrated lime to foliage. Lipp & Osburn,[2] after preliminary laboratory and field tests, discovered that 20 pounds of hydrated lime and 3 pounds of aluminum sulfate to 100 gallons of water was more effective in this respect than a number of other materials that had been tested. Field tests conducted in New Jersey during the summer of 1935 are reported in the present paper. Applications were made on apple, peach, asparagus, cultivated blueberry and rhubarb.

Apple.—The lime–aluminum sulfate spray at the rate of 20 pounds of hydrated lime and 3 pounds of aluminum sulfate to 100 gallons of water was applied to Yellow Transparent and Red Astrakhan apple trees in a large orchard at Shiloh, N. J. This location is in the district most heavily infested by the beetle, and the tests were conducted under the most severe conditions possible. Applications were made on June 25 and July 3 and 12. A few beetles were present at the beginning of the test and the height of the season was reached during the period July 10–15. Rainfall from June 25 to July 31 was 5.52 inches, but there was no precipitation until after the second application had been made.

Excellent protection was afforded to the foliage of the Yellow Transparent trees, the average injury on the treated trees at the height of the beetle season being only 5 per cent as compared with 45 per cent on the unsprayed checks. The fruit on the trees of this variety was harvested before the height of the beetle season, and the injury on the checks was negligible at this time.

The foliage of the Red Astrakhan trees which were sprayed showed a very slight injury while that on the checks showed injury ranging from 10 to 25 per cent. Prematurely ripening fruit, even when thoroughly coated with spray residue, was attacked by beetles, but fruit that ripened normally was generally uninjured. Because of beetle injury, no fruit was harvested from the check trees. As a result of the tests it was evident that lime and aluminum sulfate will afford protection from beetle attack to early ripening apples, but only when the most careful orchard sanitation is practiced. Prematurely ripening fruit will attract beetles to sprayed trees, and when such apples are consumed the beetles will feed on sound fruit even though it may be covered with spray residue. All drops should be removed as cleanly as possible, as the beetles are attracted to trees under which the apples are lying.

In spraying apples trees with lime and aluminum sulfate it is essential that the second and third applications follow the first at intervals of seven to 10 days, the last being made just before the height of the beetle season. Such treatments result in the building up of a residue that will last throughout the summer. Trees sprayed in this manner still retained heavy spray deposits on September 1, or 50 days after the last application.

[2] Lipp, J. W. and M. R. Osburn. 1935. Aluminum sulfate as a sticker for hydrated lime in sprays. Jour. Econ. Ent. 28(4): 728. Aug.

Owing to the low cost of the materials (approximately 22 cents per 100 gallons of spray material), three applications of lime and aluminum

Fig. 1.—Japanese beetles feeding on asparagus brush.

sulfate are not considered excessive, especially as several growers have been compelled to make five and six applications of other materials in order to secure comparable results. In the case of less heavily infested areas two treatments will usually be sufficient.

Peach.—A block of Hiley peach trees located near Fairton, N. J., was sprayed with lime and aluminum sulfate on June 25 and again on July 16. The beetle infestation was exceptionally heavy in this district and by July 30 the unsprayed trees showed an average foliage injury of 75 per cent. All the trees in the sprayed block were injured to the extent of approximately 35 per cent.

As the Hiley peach is not harvested until about the middle of August the residue on the fruit offered no difficulty in respect to marketing the crop. A third application would have given additional protection, but it is believed that this combination cannot be applied with safety after July 20 on Hiley trees. The grower was prepared to run the fruit through a defuzzing machine but it appeared that even this treatment would not remove all residue if later treatments were made. The protection afforded by the spray was evident by the fact that the fruit on treated trees was generally larger than that on the checks.

The Arp peach ripens early in July, and fruit from this variety is ordinarily heavily infested with beetles. On June 25 a block of these peaches located near Deerfield, N. J., was sprayed with lime and aluminum sulfate. The beetle infestation at this point was not heavy, although orchards nearby were severely damaged. As there was little injury on the foliage and fruit of untreated trees, the results of this test were not significant. Owing to the early ripening of this variety, lime and aluminum sulfate cannot be applied after July 1 on account of the residue.

On June 28 a block of Early Rose peaches at Moorestown, N. J., was sprayed with lime and aluminum sulfate. Because of the early ripening of this variety, no subsequent treatments were given. The fruit was harvested July 22–25 during the height of the beetle season at Moorestown. Approximately half the crop on the sprayed trees was destroyed by the beetle but on the unsprayed trees the crop was a total loss.

As a result of the tests conducted in 1935, lime and aluminum sulfate afforded more protection to peach fruit and foliage than any other white material previously tested. The use of this combination is not entirely satisfactory, however, because of the residue left on the fruit.

Asparagus.—The beetle causes extensive injury to asparagus brush, fig. 1. This damage cannot be controlled by dusting or spraying with lime and lead arsenate, largely because these materials do not adhere to the plants. As a result of numerous tests conducted in an eight-acre block of asparagus near Cohansey, N. J., it was found that the brush could be protected with a spray composed of 20 pounds of lime, 6 pounds of aluminum sulfate, and one-half pound of sodium lauryl sulfate[3] to 100 gallons of water. This amount of alluminum sulfate was found essential to insure proper adhesion to the foliage, and the sodium lauryl sulfate was employed as a wetting agent. Applications were made on July 15, 18, 22 and 25. Three treatments would probably be sufficient under ordinary conditions, but the period July 15–18 was marked by several severe showers and the first application was of little value. On July 30 approximately 5 per cent of the plants in the treated block were so severely injured that

[3] Cory, E. N. and George S. Langford. 1935. Sulfated alcohols in insecticides. Jour. Econ. Ent. 28(2): 257–60. April.

the entire portion of the plant above ground died. At the same time 60 per cent of the plants in the untreated section were in a similar condition. On August 20 considerable residue was in evidence on the sprayed plants and the new growth was extensive, while the check plants were generally in poor condition. Asparagus is growing rapidly at the time of infestation by the beetle, and three applications are necessary to insure adequate coverage of the brush. The interval between treatments can be determined by the rapidity with which the brush grows.

Cultivated blueberry.—The fruit and foliage of cultivated blueberries are extensively injured by the Japanese beetle. No spray has yet been developed that can be applied to the plants while picking is in progress, but several combinations have been used at the conclusion of the harvest to prevent defoliation of the plants. None of these adhered well to the foliage and frequent applications were necessary to obtain satisfactory protection.

Lime and aluminum sulfate was applied at the usual rate on July 23 to a block of Ruble and Grover blueberries located near Vineland, N. J. A second application was made July 29. The plants were heavily infested with beetles at the time of the first treatment, but few were on the plants at the time the second spray was applied to protect new terminal growth. Unsprayed plants were still heavily infested with beetles. Despite heavy rainfall two applications were sufficient to protect the plants for the remainder of the beetle season.

Rhubarb.—Rhubarb is extensively cultivated in Salem and Cumberland counties, N. J., and untreated plants in large blocks have been completely defoliated by the beetle. A large field of rhubarb located near Cohansey, N. J., was sprayed on July 15 with lime and aluminum sulfate. The plants were resprayed on July 18 and 25 because of heavy rainfall, which between July 1 and 31 amounted to 4.02 inches. On August 1 the injury caused by the beetle on the sprayed plants was negligible, while unsprayed plants had been reduced to one or two leaves and were at least 75 per cent defoliated.

Summary.—Twenty pounds of hydrated lime and 3 pounds of aluminum sulfate to 100 gallons of water protected the foliage of Yellow Transparent and Red Astrakhan apples from Japanese beetle attack, three applications being necessary in an area very heavily infested by the beetle.

Early ripening fruit cannot be protected by this spray unless careful orchard sanitation is practiced and the crop ripens uniformly.

Protection from beetle attack is afforded to peach foliage and fruit by the use of this combination, but after July 1 it cannot be applied with safety on early ripening varieties because of the objectionable residue.

Beetle injury on asparagus brush is materially reduced by three applications of 20 pounds of hydrated lime, 6 pounds of aluminum sulfate and one-half pound of sodium lauryl sulfate, to 100 gallons of water.

The foliage of cultivated blueberries and rhubarb can be protected by two or three applications of lime and aluminum sulfate at the same concentration as that employed on peach and apple.

NOTES ON BIOLOGY AND CONTROL OF THE ASIATIC GARDEN BEETLE[1]

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Fourteen years have elapsed since the Asiatic garden beetle, *Autoserica castanea* Arrow, was discovered in a nursery near Rutherford, N. J. The insect has evidently found conditions in this country well suited to its rapid increase, as its preferred food plants are abundant and the climate appears to be favorable. The activities of this insect have been under investigation since 1927, and much of the information obtained has been published. In this paper will be presented certain heretofore unpublished data on the distribution of the insect, its feeding habits, the injury caused by larvae and adults, and the control of the insect in the larval and adult stages.

Distribution.—The Asiatic garden beetle has been found at many widely scattered points in the Atlantic seaboard states of Connecticut, Delaware, Maryland, Massachusetts, New York, New Jersey, Pennsylvania, South Carolina and Virginia, as well as in the District of Columbia, fig. 1. There is a zone of continuous infestation which centers about New York City, extending in New York state north to Peekskill and east to Smithtown on Long Island, in northeastern New Jersey west to Morristown and south to Bound Brook and Asbury Park, and into Connecticut to include the southwestern third of Fairfield county. In this zone beetles may be expected in all places where conditions are favorable for their development.

Beyond the area of continuous infestation there is a zone of discontinuous or localized infestations, many of which are widely separated. Some of the most distant outlying colonies are located at Agawam, Mass., Aiken, S. C., and East Falls Church, Va. The infestation in and around Philadelphia, Pa., is an old one, and here the beetle is now known to have spread into Chester, Delaware, Montgomery and Philadelphia counties. In New Jersey there are now so many local colonies that it is probable that within the next few years, in addition to the heavy infestation in the northeastern part of the state, a rather general light infestation will cover much of the central part. The insect has been known to occur in Washington, D. C., for more than eight years, but there is little evidence that it has noticeably increased in abundance there. It is possible that conditions have been less favorable for its development in Washington than at other points along the Atlantic seaboard. The colonies in Connecticut that are still outside the zone of continuous infestation have increased in strength, and Dr. W. E. Britton, state entomologist of Connecticut, reports that plant injury has now occurred at New Haven and Danbury. Local colonies may now be found at several other outlying points, as indicated on the map.

Our present knowledge of this pest does not permit a definite prediction as to its behavior as it moves into territory remote from the present area of distribution. Certain factors, however, which should influence

[1] *Autoserica castanea* Arrow, order Coleoptera, family Scarabaeidae.

the future activities of the beetle in other parts of this country have been determined. A shortage of soil moisture at the time eggs and small larvae predominate in the soil will probably cause a high mortality of these forms. This condition occurred in the New York area in 1929 and 1930, and as a result the beetle population was greatly reduced (*2*). It seems

Fig. 1.—Known distribution of the Asiatic garden beetle in the United States, to January 1936.

probable, therefore, that the beetle will not thrive in certain inland places where the summer rainfall is markedly below that of New York City.

Because of the higher temperature in the southern states, it is probable that the insect, if introduced, will thrive there wherever the rainfall is adequate. That a partial, if not complete, second generation of beetles may be expected each year in some of these states may be anticipated from the fact that, when beetles were reared in the laboratory at a constant temperature of 81° F, three successive broods developed from the

egg to the adult stage, without diapause, between September 1 and June 30 of the following year. Since the Asiatic garden beetle flies extensively and feeds voraciously on hot nights and scarcely at all on cool nights, it may also be expected that the rate of spread will be accelerated and plant destruction increased as the insect moves southward and encounters higher temperatures.

Preliminary data indicate that soil type or some soil condition not now thoroughly understood may prevent the Asiatic garden beetle from becoming a pest in some localities. Laboratory and field cage tests have shown that a higher larval mortality occurs in Hempstead loam than in any of four other common Long Island soil types that have been tested. The insect has not become economically important in that portion of Nassau county where Hempstead loam is the prevailing soil, though extensive plant destruction has occurred with other soil types immediately north, west and south of the Hempstead Plain.

Abundance of the beetles about lights.—Field studies have shown a considerable increase in the beetle population in the area of continuous infestation during the past two years. One of the most noticeable signs of this increase has been the unusual concentration around bright lights on warm nights during July and August. Beetles have been attracted to stores and places of outdoor amusement in such large numbers that the proprietors have repeatedly complained that customers have been driven away. Places that suffer most often from these nightly flights are carnivals, baseball parks, golf driving courses, dog race tracks, roadstands, open-air restaurants, and swimming pools in the suburban areas around New York and Philadelphia. In these heavily infested localities it is not unusual to find thousands of beetles on the store fronts and screen doors of drugstores and restaurants that operate during the evening and display illuminated signs. Beetles have been especially abundant where blue mercury vapor signs have been used.

Injury in vegetable gardens.—Although the Asiatic garden beetle has developed into a real nuisance around lights and, as in the past, has caused considerable injury to ornamental plants, during the past three years more concern has been shown over the extensive destruction of vegetables. An account of this injury in the subsistence gardens of the unemployed on Long Island in 1933 has been published by the writer (*4*). This destruction of vegetables by the beetle in both the larval and the adult stages continued during 1934 and 1935 at points in Nassau, Queens and Westchester counties in New York state and in a few localities in Connecticut and New Jersey. In some cases the feeding resulted in complete destruction of the preferred vegetable food plants in the gardens attacked. Plants that escaped destruction by the larvae were riddled by the beetles. The vegetable garden plants that have been attacked most often by the larvae are beets, carrots, corn and strawberries, while the adults have been most destructive to carrots, beets, eggplant, kohlrabi, parsnips, peppers and turnips.

In the fall of 1933 surveys to determine the abundance of the larvae in cultivated areas were made in three heavily infested garden tracts located near East Norwich, Glen Head and Locust Valley, N. Y. These

diggings, each 1 yard square and 12 inches deep, were 75 feet apart lengthwise and 50 feet apart crosswise of the tracts. The total areas examined were 33 square yards at Glen Head, 30 square yards at East Norwich, and 46 square yards at Locust Valley. In all cases the larvae were more numerous in the weedy grassland at the sides of the gardens than in the gardens themselves, but heavy infestations were also found where beets, corn, carrots and tomatoes had been grown. In these three gardens there were 32 diggings, which showed larval populations ranging from 100 to 411 per square yard. Experience has shown that where larvae in a garden are in excess of 100 per square yard considerable plant destruction may be expected. The larval populations in the three gardens are shown in table 1.

Table 1.—Larval populations of the Asiatic garden beetle in three cultivated gardens on Long Island in the fall of 1933.

Situation	Average Number of Larvae per Square Yard		
	East Norwich	Glen Head	Locust Valley
Corn plants	80	98	141
Tomato		24	155
Carrot			108
Beet	120		134
Cabbage			43
Weeds	80	64	62
Bare ground	3		
Sod at side of garden	289	445	461

Factors influencing oviposition and larval abundance.—Observations on larval abundance during the period 1927–34 have indicated that the Asiatic garden beetle is influenced in its choice of places to oviposit by the presence of certain plants. In 1932 the writer (*3*) indicated that larvae were always more numerous in grassland, especially when overgrown with weeds, than in other situations. Field observations have shown that in these weedy places the presence of orange hawkweed, goldenrod, wild aster, and to a lesser extent white clover, attracts the beetle for oviposition. Field surveys have clearly demonstrated that areas with a heavy growth of orange hawkweed will have from five to 10 times as many larvae as neighboring sodland without this weed, and in cage tests, to be discussed later, larvae have been at least one third more abundant in orange hawkweed plots than in plots of other plants.

The increased larval abundance around goldenrod, wild aster and white clover is to be expected, as they are favored food plants of the beetle. On the other hand, the larval abundance around such plants as orange hawkweed, corn and tomatoes is rather surprising, as the adult beetle feeds little, if any, on these plants. Although these plants differ widely in their form of growth, they are alike in one respect, namely, that their dense foliage shades the ground and makes the soil beneath them cooler and more moist than it is in more exposed situations. Beetles choose places where the ground is relatively cool and moist in which to hide during the daytime, and this fact no doubt accounts for the increased egg deposition and larval occurrence in such places. During the day one third more beetles have often been found in the ground on the shaded side of rose bushes and dahlias than on the sunny side of the plants.

Beetles feed to a slight extent on sorrel, but it is not a favored food plant. In the dry summers of 1929 and 1930, however, large numbers of beetles were found during the day in the ground beneath sorrel plants that were growing in moist places. The larval population where this plant predominated increased during these two years, until it ranged from 50 to 345 per square foot, while in drier, more normal situations, larvae became relatively scarce.

In a plot on the laboratory grounds beetles fed only a moderate amount on peanut, and yet the larval population was very high around this

Table 2.—Reaction of Asiatic garden beetles to plants in the plant-preference cages.

Plant	Relative Abundance of Adults, Per Cent[2]		Choice of Place for Oviposition, Measured by Larval Abundance, Per Cent[2]	
	1933	*1934*	*1933*	*1934*
Aster	32		26	
Beet, garden		2		7
Beet, sugar		7		22
Cabbage		2		26
Carrot[3]	100	3	46	23
Carnation	3		56	
Chrysanthemum	91	100	45	15
Cotton	15		26	
Delphinium	7		20	
Goldenrod		15		23
Grass, short	16		31	
Grass, long	6	9	20	8
Iris	3		23	
Orange hawkweed	20	11	100	100
Peanut		38		92
Radish	18		19	
Sedum acre	4	5	29	5
Shasta daisy		3		7
Snapdragon	5		45	
Strawberry, not mulched	26	12	59	42
Strawberry, mulched	31	17	20	7
Turnip		7		39
White clover	10	16	61	52

plant, table 2. Peanut plants have an abundance of dense foliage, which shades the ground and creates the cool, moist condition which is favored by the beetles as a hiding place in the daytime and also for oviposition.

Carrot is one of the favored food plants, but when this crop is grown on a commercial scale the total feeding has never been sufficient, even when the beetle population was heavy, to prevent the carrots from affording an ideal daytime hiding place for the beetles. On the other hand, this condition has resulted in larval population about carrots in some truck garden farms in the vicinity of New Hyde Park and Valley Stream, N. Y., sufficient to destroy vegetables grown on this ground the following year.

[2] Expressed in percentage of number on most favored plant.

[3] Carrot is not ordinarily a more favored plant than chrysanthemum. The low percentage of adults in the carrot compartment in 1934 was due to the lack of carrot foliage, as these plants were entirely defoliated at the beginning of the season when still small.

Cage studies of feeding preferences and choice of places for oviposition.—A study to determine the preference shown by the Asiatic garden beetle for plants on which to feed and oviposit was conducted in a large field cage during the summers of 1933 and 1934. The top and sides of the cage, which was 24 feet long, 4 feet wide and 2 feet high, were covered with 18-mesh wire screening to prevent beetles from escaping. Within the cage they could move about freely. The plants being tested were grown in compartments 4 by 1½ feet, which were separated below the surface of the ground by strips of tin sunk to a depth of six inches. This prevented the larvae from moving out of their compartment. The sides of the cage were extended below the surface of the ground to a depth of 12 inches, and this portion of the cage was constructed of wood. This prevented larvae from moving out of the cage.

When the tests were started early in July, equal numbers of beetles were placed in each compartment of the cage, the total being 1040 in 1933 and 1190 in 1934. The relative attractiveness of the plants for feeding was determined by counting the beetles on the plants at night with the aid of a flashlight. Each fall the cage was dug up and the larvae in each compartment were counted to determine the influence of the plants on oviposition. The numbers of beetles on the plants were expressed as percentages of the number feeding on the most preferred plant (carrot in 1933 and chrysanthemum in 1934). The relative abundance of the larvae around the various plants was expressed as a percentage of the number found in the orange hawkweed section of the cage, as this has been the preferred plant for oviposition by the beetle under all conditions. A summary of the data obtained in these cage experiments is given in table 2.

Preferred food plants.—A list of the food plants of the Asiatic garden beetle adult in the present heavily infested area has been compiled as a result of many field observations. From the information gathered it is known that the beetle may feed on more than 100 species of plants, though the preferred food plants number only about 30. Since the publication of the food-plants list in 1932 (*3*), data have been obtained which show that some additions to this list should be made, and a revised list of the preferred food plants is given. The shrubs most commonly attacked are box elder, butterflybush, devil's walkingstick, Japanese barberry, oriental cherry, rose, sumac and viburnum. The most favored flowers are those of aster, chrysanthemum, dahlia, delphinium, gaillardia, goldenrod, hemp, sunflower and strawflower. Both blossoms and leaves of these plants are attacked, and in the heavily infested area it is not unusual to observe gardens in which from 20 to 60 per cent of the blooms have been ruined, and there have been cases where over 90 per cent of the flowers have been destroyed. Of the common fruit trees, the foliage of peach and cherry is attacked. The leaves of strawberry also are eaten. In vegetable gardens serious injury often occurs upon such plants as carrot, beet, eggplant, kohlrabi, parsnip, pepper and turnip. In heavy infestations, when the more favored food plants have already been destroyed, broccoli, cabbage, spinach and Swiss chard may also be severely attacked.

Influence of temperature on feeding.—Heavy destruction in gardens occurs only on warm nights, as beetles fly but little when the temperature is below 70° F, and without flight they do not concentrate on the preferred food plants. On warm nights a few beetles may continue to feed until the temperature has fallen to 65° F, and in rare cases some have been observed to feed at temperatures as low as 60° F. At temperatures between 60 and 70° F, even though they do not fly, beetles leave the ground and feed to a lesser extent on plants near their daytime hiding places. It has been noted that on such nights a larger number of beetles will come out and feed after a period of several nights when there has been little feeding, than after a warm evening when the beetles have fed actively. During the past eight seasons approximately 90 per cent of the injury to plants has occurred between July 10 and August 15.

Table 3.—Relative abundance of the sexes of the Asiatic garden beetle.

Situation	Individuals Examined	Percentage of Sexes	
		Males	Females
Feeding on preferred food plants	825	67	33
Reared (field-collected larvae and eggs)	123	52	48
Prior to July 15 diggings, sod land	257	55	45
After July 15 diggings, sod land	311	28	72
Diggings under chrysanthemum and roses			
July	304	77	23
August	927	65	35
September	82	55	45
Trap (500-watt daylight bulb)	1224	80	20
On plants in lighted area around trap	490	75	25

Abundance of the sexes under various conditions.—Nearly 70 per cent of the defoliation in the ornamental and vegetable gardens has been caused by the feeding of the male beetles. As the season progresses, the percentage of females found in sod land and in the soil beneath food plants increases. Data on the relative abundance of the two sexes, in various situations during the past four seasons, are presented in table 3.

Studies on control of larvae.—Experiments have been conducted on Long Island which have shown that complete protection from the attack of larvae of the Asiatic garden beetle on turf in lawns and golf courses can be obtained. It is recommended that acid lead arsenate be used on established lawns at the rate of 10 pounds to 1000 square feet. Complete information on the methods of applying this treatment to turf is given in a publication by Fleming & Osburn (*1*).

Some data have been obtained which indicate that at least partial protection from larval attacks in strawberry beds can be obtained by a cultural procedure. In the plant-preference studies, table 2, a considerable reduction in the larval population in strawberry plots was obtained by mulching with hay. These tests must be considered preliminary in nature, as there were only two plots in 1933 and four plots in 1934, each six square feet, from which data were obtained. The results showed, however, that mulching of the plants brought about a 65 per cent reduction of larvae in 1933 and an 83 per cent reduction in 1934, as compared with the plots where the strawberry plants were not mulched. Similar protection by mulching has been obtained in gardens on estates in areas where

extensive injury to strawberries was occurring. Larvae of the Asiatic garden beetle have never been observed to injure seriously strawberry beds which have been mulched, even when other plants in the garden have shown extensive injury.

Although no experiments have been conducted to determine the value of plants as trap crops, field observations and grub surveys in nurseries indicated that orange hawkweed or some other less objectionable plant might be used for this purpose. When orange hawkweed is present, beetles lay a large percentage of their eggs around this plant. It is possible that if a trap crop of this type, which could be grown along the border, were grown in soil treated with lead arsenate to kill the larvae, the beetle population around cultivated plants in the garden would be reduced.

Most of the extensive larval damage to vegetable gardens has been on heavily infested overgrown land that has been plowed up in the spring and planted to vegetables. The only vegetable that has survived the larval attack in such cases is the potato. Though not yet substantiated by field tests, it is probable that, if this overgrown land, when plowed up, were planted to potatoes the first year, the larval population the next year would be greatly reduced. Adults of the Asiatic garden beetle feed very little on the potato plant, and it is presumed that many would leave the potato fields to feed and oviposit in other places.

Studies on control of beetles.—The problem of protecting plants from the attack of the adult beetle is difficult, since a satisfactory repellent has not been developed, and in ornamental gardens throughout the heavily infested area the sprayed foliage of preferred food plants is often completely eaten by successive hordes of invading beetles. Beetles that feed on the sprayed foliage are killed, but each warm night a new lot of beetles flies to and attacks the plants. On the other hand, in cases of moderate infestation, where there is little likelihood of repeated reinfestation, a spray of 3 pounds of lead arsenate and 2 pounds of flour to 50 gallons of water has given adequate protection (*3*). During the summers of 1933 and 1934 experiments with a poisoned bait were conducted in an effort to protect vegetable garden plants from attacks by the beetle. This work has not progressed sufficiently to permit definite recommendations to be offered at this time, but the preliminary results look promising.

While the experimental work with insecticides was being carried on, efforts were made to develop light traps to catch the beetles. An efficient and cheap trap, which was perfected in 1934, has a funnel 12 inches in diameter at the top, seven-eighths inch in diameter at the bottom, and $11\frac{1}{2}$ inches deep. The four wings of a baffle located above the funnel are each 16 inches wide by 16 inches high and extend $2\frac{1}{2}$ inches into the top of the funnel. A screw top for attaching a fruit jar, to receive the beetles entering the trap, is soldered to the bottom of the funnel. In this trap a 100-watt electric daylight bulb is inserted in an opening cut in the baffle at the junction of the four wings. When in use, the trap is supported on a half-inch galvanized-iron rod, so that the light is about five feet from the ground. This trap has captured as many as 2000 beetles per hour on a night of extensive flight, and the average catch when in use in the summer of 1934 was 930 per hour.

Summary.—The Asiatic garden beetle is most abundant in the suburban areas around New York City and Philadelphia, but isolated local colonies occur in Connecticut, Delaware, Maryland, Massachusetts, New York, New Jersey, Pennsylvania, South Carolina and Virginia. Each year the insect is spreading outward from these infested areas, and if it continues to do so it will become established in many other parts of the United States, except where it encounters in its spread places with low summer rainfall or unfavorable soil conditions.

The Asiatic garden beetle is a nuisance on warm summer nights because of its concentration about bright lights. The destruction of ornamental plants has been noted each year since the insect has become established, but injury to vegetables has occurred only during the last three years.

The larval population at any point is dependent on the choice of places for oviposition by the female beetles. Some data from field surveys and cage tests are presented to show the influence of various plants and other factors on larval abundance. Plants that shade the ground and keep the soil more moist and at a lower temperature than is found in more exposed situations make a condition favorable for the hiding of adults during the daytime as well as for oviposition.

Males predominate in collections on plants at night and in traps, especially early in the beetle season. As the summer advances the percentage of females in sod land and around favored food plants increases.

The turf of lawns and golf courses may be protected from injury by larvae of the Asiatic garden beetle by treating the soil with acid lead arsenate. Mulching with hay will help to protect strawberry plants, and it is possible that the use of trap crops and proper selections of plants will avoid injury in vegetable gardens.

In heavily infested areas it is difficult to protect preferred plants from attacks by the beetles owing to the continued influx of beetles to such plants each warm night. In light infestations a spray of acid lead arsenate and flour helps to protect the plants. Other possible control methods for the adult include the use of light traps and poisoned bait.

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The Bureau of Entomology and Plant Quarantine announces the revision, effective March 16, of the quarantine relating to the Japanese beetle, the principal change being the extension of the regulated area to include additional townships in two counties in Maine, five in Maryland, one in New York and seven in Virginia.

OIL EFFECTS ON SHADE TREES

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The need for a safe, satisfactory summer oil has been very pronounced in shade tree work. The best oils in use at the present time for foliage sprays give satisfactory control of certain pests on some trees, but they are in such form as to be difficult to manipulate or are quite expensive or both. Then, too, there is a great deal to be learned in regard to the effect of oils on the foliage of different trees. In connection with an investigation into the properties of summer oils during the season of 1935, some rather interesting effects on foliage were noted and are considered worthy of report. These tests were conducted at the Bartlett Tree Research Laboratories, Stamford, Conn. Acknowledgement is due Dr. Henry B. Faber of the Swann-Finch Oil Corporation and Mr. A. P. Frame of the Cities Service Company for their cooperation and helpful suggestions given in the development of this investigation.

Types of oils used.—We chose four types of emulsifiable oils for comparison in these spray experiments. These we may designate A, B, C and D.

A.—A widely used commercial white oil paste-form summer spray
B.—A free-flowing oil of the aromatic series, not as yet marketed for spray purposes
C.—A free-flowing oil of the naphthenic series, not as yet marketed for spray purposes
D.—A widely used dormant oil, sulfonated and washed with caustic, free flowing.

Foliage injury tests.—Tests were first conducted to determine the comparative amount of foliage injury to be expected on the more delicate types of trees. Aspen, *Populus tremuloides*, and sugar maple, *Acer saccharum*, were chosen from the deciduous trees; red pine, *Pinus resinosa*, and red cedar, *Juniperus virginiana*, from the conifers.

All tests were conducted under the summer conditions usually existing in the region of Stamford, Conn. In all cases applications were made during the late forenoon or early afternoon. While this was the period of highest temperatures, at no time on the days when tests were run did the temperature exceed 90° F. Hand sprayers were used for the preliminary tests, power machines for the later applications.

For the first test, oils A, B, C and D were applied at strengths of 1 per cent, 5 per cent and 10 per cent respectively. Foliage injury developed within a day or two on the deciduous trees, aspen and maple, but not on the conifers. Injury on the latter did not definitely appear until three months later at the time of normal leaf-drop. At that time needles, in addition to the normal drop, fell on the injured branches. On the red pine, for instance, which this year should drop its 1933 leaves normally, the spray-injured branches dropped many or most of the 1934 crop and in some cases even some of its 1935 growth in addition to the 1933 needles. On the sugar maple and poplar, the leaf-scorching or spotting showed up

quickly and the oils were rated from the standpoint of safety in the following order with A the safest: A, B, C and D. A and B were relatively safe, but C. and D gave severe burning, varying, of course, with the concentration. The 10 per cent gave injury in the case of all four oils, while the 1 per cent gave no injury with A or B, but did with C and D. The check-up on the conifers three months later gave parallel results, except that here the rating of A and B was reversed, the B causing slightly less injury than A.

A comparison on a wide variety of trees was next tested, using 10 per cent concentrations of both A and B. Branches of the following were sprayed: chestnut, rose, filbert, black walnut, Siberian elm, white ash, ginkgo, catalpa, tulip, American elm, silver maple, Norway maple, European linden, red oak, Norway spruce, Scotch pine, white pine, sweet cherry, sour cherry, pecan, apple, hickory, flowering dogwood, and the garden-vegetables bean and lettuce. In general, less injury developed with A than with B, although injury on most of the foliage occurred with both oils. B usually produced a spotting of the foliage, followed in some cases by leaf drop, while A produced a green mottling on the undersides or margins of the leaves which did not turn brown and dry out until later. In other words, the injury with B developed much more rapidly than with A. It was interesting to note that neither spray at this strong concentration of 10 per cent produced injury on catalpa. The silver and Norway maples, tulip tree and white ash showed the most severe injury.

Comparison of spread.—As these preliminary tests definitely precluded the practical use of both C and D as general foliage sprays, while at the same time it showed A and B to be somewhat comparable in safety, it was decided to run further tests with B. The large amount of emulsifying agent used in A to produce its pastelike consistency necessarily meant a reduction in the actual amount of oil used, so that a 10 per cent concentration of A would really contain considerably less actual oil than B. It was decided to run further tests with B on a basis comparable to the normal dilutions of A, which is a standard summer spray. A drop of oil A was dropped on the surface of still water and the area of spread measured. This test was repeated with B. The area of spread of B was three to four times that of A, showing that the surface tension coefficient of B was that much lower than A. By proportioning the concentration of the emulsion inversely to the area of spread, the spreading property of B was equalled to A and the resulting spray tests showed that at the normal foliage concentrations B was as safe to use as A, as a general foliage spray.

Compatibility of oil B with other spray materials.—Oil B was then tested as to (1) its compatibility with the usual spray materials, (2) as a spreader for such, (3) as an insecticide, and (4) as to its effect on a variety of trees, applied by a power sprayer at a chosen concentration of one-half of one per cent.

Oil B was found to be compatible with arsenate of lead, Bordeaux mixture, nicotine sulfate, several colloidal and wettable sulfurs, and also different combinations of these with calcium caseinate and other stickers and spreaders of this general type. It was not compatible with lime sulfur and produced injury on foliage carrying a residue of lime sulfur. A case

was reported of light injury on hemlock following the application of this oil plus a colloidal sulfur. This combination should therefore be used with caution. In another test, this oil used with a commercial copper product produced injury on petunias and rose and this combination should also be avoided.

Oil B as a spreader.—Oil B gave excellent spreading properties to arsenate of lead, Bordeaux and several wettable sulfurs used with and without stickers. It acted as a very effective carrier and wetting agent for nicotine sulfate. Its mechanical qualities were excellent, producing a spray combination which reduced back pressure in the bucket pump, and reduced friction in the nozzle where the power machine was used.

Oil B as an insecticide.—Oil B possessed some insecticidal properties *per se*, but the addition of nicotine sulfate 1–800 produced an effective aphicidal and red mite spray which could be used with safety at the standard dilution on foliage carrying a residue of arsenate of lead or of sulfur (not lime sulfur). At one-half per cent concentration plus Black Leaf 40 (1–800) practically 100 per cent kills of the black aphid on white pine, *Dilachnus strobi* (Fitch); the gray aphid on mugho pine (provisionally determined by Professor Miriam A. Palmer as *Eulachnus rileyi* Williams); the Norway maple aphid *Periphyllus lyropictus* (Kess.); the filbert aphid *Monellia* sp.; and the hickory aphid on black walnut, *Monellia caryella* (Fitch), were obtained. Very high kills were obtained with this combination on the adults of the oak red mite *Paratetranychus bicolor* on both pin oak and silver maple, while a considerable ovicidal effect was noted here also.

With the pear psylla and persimmon psylla this oil plus nicotine gave a high kill of exposed nymphs. Protected nymphs and adults were only poorly killed, as in usually the case with contact liquid sprays for these insects.

No appreciable kill with this concentration was obtained in the case of mealy bug on gardenia or Euonymus scale on bittersweet.

Effect of B at one-half per cent on foliage.—No injury with this concentration, either when used alone or with arsenate of lead, Bordeaux, nicotine sulfate or a sticker such as calcium caseinate or Triple S, or with a combination of these, resulted on the following:

The conifers: red, Scotch, white, mugho, Japanese red, Japanese black or Japanese white pines; balsam or Douglas firs; Norway spruce, hemlock and red cedar.

The deciduous shade trees: American and red elm; sugar, silver and Norway maples; red and pin oak, aspen, white ash and European white birch.

The shrubs: flowering dogwood, viburnum, sumach and spiraea.

The nut trees: black walnut, shagbark hickory, chestnut, pecan, filbert, hazel nut and butternut.

The fruit trees and vines: apple, black and sour cherry, plum, pear, grape and persimmon.

In fact, at this concentration, no definite injury resulted on any of the trees to which it was applied.

Size of oil globules.—In the course of these tests, observations were

made which tended to indicate that certain factors possibly affected oil injury to foliage. By microscopic measurements, a comparison of the sizes of the oil globules in the four emulsions was made.

A.—Smaller globules fewer than others. Many enormous, unbroken oil globules. Average size of smaller globules 2.4μ

B.—Small globules most numerous. Only a few large globules. Averages size of smaller globules..... .9μ

C.—Small globules most numerous. Only a few large. Average size of smaller globules..... .9μ

D.—Numerous large globules, none as large as in A. Larger globules up to 9μ. Average size of smaller globules 1.6μ

The spray tests indicated that the size of the globule was not an important factor with the different oil stocks at least, D and C both being more injurious than B. To check these results, oils B and C were treated to increase the size of the globules. No change in the relation of injury to foliage occurred.

Aromatic vs. naphthenic oils.—We may get a clue to the harmful action to foliage by comparing B with C. The viscosity, sulfonation, saturation, size of globules in the water emulsion, and the spreading area or surface tension factor, were alike. Yet B was much safer on foliage than C.

There was one essential difference between the two oils B and C. B was from an oil of cyclic origin, possibly of the aromatic series, whereas C was from an oil of naphthenic origin.

Hydrolysis plays an important part. Sulfonation of the ring gives sulfonates extremely hard to hydrolyze, whereas there is some doubt of oils of naphthenic origin hydrolyzing after sulfonation in the same way. That the sulfonation and subsequent amount of hydrolysis plays an important part in connection with damage to foliage seems obvious.

It all comes down to this—the sulfonates should be of such stable character and quality that a satisfactory oil emulsion can be made with as little emulsifying oil as is practical to carry the other ingredients of the summer spray.

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RESULTS WITH HOME-MADE OIL EMULSIONS FOR ORCHARD SPRAYING[1]

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Due to the general tendency towards economy in insecticides, especially during these years of depression, many orchardists in New Jersey leaned towards preparing their own emulsions for delayed dormant spraying. This was started on a small scale in 1934 and on a much larger scale in 1935 when about 40,000 gallons were prepared. The formulas for preparing the emulsions had to be, of necessity, simplified so as to meet the scanty equipment on the farm. After preliminary laboratory experiments several formulae were worked out, some of which were successfully used by the farmers, employing the ordinary orchard power sprayer equipped with suitable paddles and pumps, for the emulsification process, and are here presented.

Dormant oil emulsions.—In New Jersey, oil emulsions are extensively applied as a delayed dormant spray to control scale and overwintering eggs of red mite and of aphids. For this purpose the oil need not be highly refined. Petroleum-distillate light lubricating oils, preferably from a paraffin base, ranging in viscosity from 80 to 140 Saybolt at 100° F, are usually used in the manufacture of commercial oil emulsions. A well-known brand of oil widely used is Diamond Paraffin, possessing the following specifications:

Gravity (A.P.I.)	24–28
Viscosity (Saybolt 100° F)	108–113
Boiling range	650–770° F
Color	straw to amber

In large quantities such an oil can be purchased at about 7 cents per gallon. A good emulsion can be readily prepared by one of the following formulas.

Formula 1

Oil	100 gallons	66% oil
Water	45 gallons	
Soap	5 gallons (liquid containing 30% potash soap)	

Any other suitable potash liquid soap or semiliquid soap readily soluble in cold water can be used, but the quantity added should be sufficient to give concentration of about 1 per cent actual soap in the stock emulsion. Prepared by this formula the oil emulsion will contain 66 per cent oil. Solid soaps are not convenient because heat or long standing in water is required to dissolve them. The various commercial brands of liquid potash soaps that are readily soluble in cold water contain from 20 to 40 per cent actual soap.

Procedure.—Add the soap and water to the tank and mix thoroughly; allow the oil to run gradually into the tank with agitators and pump

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

running at full speed or at about 200 pounds pressure. After all the oil has been added, pump the mixture out through the hose and back into the tank for about 30 minutes, or long enough for the entire mixture to pass through the pump two or three times or until the mixture appears thick and homogeneous with no free oil on the surface. Excessive foaming may be eliminated by adding 2 quarts of kerosene in which about 2 pounds of wool grease (Degras) has been dissolved. Pump the finished product into drums for storing.

Where the water used for spraying is exceptionally hard, formula 2 should be used in preparing the oil emulsion.

Formula 2

Oil	100 gallons	70% oil
Water	42 gallons	
Casein (fine powder)	3 pounds	
Ammonium hydroxide (28% ammonia)	1 quart	
Cresylic acid	1 quart	

Procedure.—Pour the water into the spray tank; with the agitators working, add the ammonia; sift the casein in slowly. After all the casein has dissolved, which takes a few minutes, mix the cresylic acid with the oil and allow the mixture to run into the tank gradually with the agitators and pump running at full speed or at 200 pounds pressure. After this step, the procedure is exactly the same as in the preparation of formula 1.

A multiple of either one of these two formulas can be used to prepare any quantity desired. If stored at temperatures above freezing these stock emulsions may remain stable for a long time. Samples prepared about two years ago and kept in the laboratory have not yet shown any signs of breaking.

Formula 3

Oil	100 gallons
Water	48 gallons
Glutrin	2 gallons

Glutrin is a cheap by-product in the wood pulp industry and costs considerably less than either soap or ammonia-casein emulsifiers. The petroleum oil emulsion produced by glutrin, however, does not remain stable for more than one or two days (unless prepared by colloidal mill process) and is therefore not suitable for storing.

Procedure.—The glutrin and water are mixed in the tank and the oil then pumped in and emulsified as described above.

During 1934 formula 3 was used exclusively, while in 1935 formula 1 was largely employed. Soap, in addition to its advantages in stability for storing purposes, also produces an emulsion possessing better spreading properties than the glutrin.

The emulsions thus prepared were compatible with cresylic acid (extensively used in New Jersey for the control of aphis eggs) and were comparable in every respect with the commercial oil emulsions, as far as the control of aphis and red mite is concerned. The approximate cost of the home-made emulsion was about 7 cents per gallon, time, labor and

machinery included, as compared with 13–18 cents of the various commercial emulsions.

Summer oil emulsions.—Encouraged by the considerable saving of money in the home-made preparation for dormant spraying there has been a tendency among several growers towards home-made emulsions also for summer spraying. Summer oil emulsion with lead arsenate is used in a number of orchards heavily infested with codling moth in southern New Jersey. Also under certain conditions a 1 per cent summer oil emulsion spray is used to control red mite. Due to the danger of foliage injury the selection of the oil and the process of emulsification are of greater importance here than in dormant spraying. For these reasons the writer considered it expedient to conduct field experiments with several formulas before assuming responsibility of recommending any one formula to the growers.

Two grades of oil obtained from L. Sonneborn Sons, Inc., of the following specifications were selected for these tests.

	Grade A	Grade B
Specific gravity	.835–.845	.835–.845
Viscosity (Saybolt 100° F)	65–75	65–75
Unsulfonatable residue	Above 97%	90–94%
Initial boiling point	600° F	550° F
Distillation end point	750° F	730° F
Color	water white	pale
Odor	none	petroleum

As it appears from these specifications the outstanding difference between the two oils lies in the degree of sulfonation, grade A being more refined, possessing the highest per cent unsulfonatable residue.

Since the summer oil emulsions are directly mixed with lead arsenate, soap and similar alkaline emulsifiers cannot safely be used due to the possible liberation of soluble arsenic with resultant injury to foliage. The oils were therefore emulsified by formula 2, previously mentioned, and by two neutral emulsifying agents as follows:

Formula 4

Oil	100 gallons	70% oil
Water	42 gallons	
Gardinol	6 pounds	
Defoamer about (Kerosene containing 50% wool fat)	2 quarts	

Formula 5

Oil	100 gallons	70% oil
Water	42 gallons	
Aresklene	6 pounds	

Gardinol is a sodium salt of sulfated lauryl alcohol, while aresklene is a sodium salt of sulfated butyl-o-hydroxydiphenyl. In each case the emulsifier was dissolved in the water and the oil gradually pumped in and emulsified by the process already described. The cost of preparing the emulsion was about 25 cents per gallon for the grade B oil.

The emulsions were given to a farmer who applied them on large blocks of trees, consisting of Stayman, Wealthy and Rome varieties, alongside

other similar blocks receiving a commercial oil emulsion (Orthol K). He followed the New Jersey special schedule to control codling moth under heavy infestation. Each block received four oil–lead arsenate cover sprays of about .5 per cent actual oil in addition to three standard lead arsenate cover sprays without oil, during the spraying season.

Close observations by Dr. Driggers and the writer have disclosed practically no differences between the home-made emulsions, prepared by any one of the three formulas, and the commercial emulsions, either in the control of codling moth or in the effect on the tree and foliage. Wherever injury to foliage occurred it was pronounced to the same extent and approximately during the same period on all the blocks sprayed with oil regardless of whether home-made or commercial emulsions were applied. Neither were there any differences observed between the two grades of oil.

Since these tests constituted a part of a larger experiment on codling moth control conducted by Dr. Driggers during several successive seasons, the results from the standpoint of codling moth control with the different oil–lead arsenate and standard lead arsenate sprays are fully described by him elsewhere. In presenting these results the writer was merely concerned in comparing several formulas of home-made with commercial oil emulsions applied under identically the same conditions, and on the same varieties of trees.

Summary and conclusions.—A comparative study was made between commercial oil emulsions and home-made oil emulsions in spraying apple orchards. For summer spraying highly refined oils were employed, while for dormant spraying an unrefined light lubricating oil was used. The emulsions were prepared in the ordinary orchard power sprayers, equipped with mixers and high pressure pumps.

The results show that both types of oil emulsion produced equally efficient control on eggs of red mite and aphis when applied as delayed dormant sprays in combination with cresylic acid. The home-made summer oil emulsions compared well with the commercial products as far as both the control of codling moth and foliage injury are concerned. Several formulas for preparing home-made oil emulsions are suggested.

SOAP WASHES AND OIL EMULSIONS AS SUMMER SPRAYS FOR PEACH[1]

S. W. Frost, *The Pennsylvania State College*

Experiments conducted during the summer of 1935 consist of orchard treatments and laboratory tests. The orchard treatments were made on a rather significant scale in two Adams county peach orchards. Blocks of seven trees were sprayed at the time of the shuck fall and twice during the summer in June and July. These sprays were applied with standard orchard spray equipment and 400 to 450 pounds pressure. The trees were comparatively small and the spraying was done with a gun from the

[1] Paper No. 710, authorized December 1935, Pa. Ag. Exp. Station.

ground, applying approximately 3 gallons per tree per application. A medium grade of Orthol K was used in all the tests at the rate of 2 gallons to 100, or 1.7 per cent actual oil by volume, a higher per cent than is generally considered necessary to kill red spiders. Rex basic arsenate of lead, 4 pounds to 100, was used in the shuck-fall in the Raffensperger

Table 1.—Percentage of foliage injury (based on 1000 leaves) resulting from sprays applied to peach, 1935.

Treatment[1]	June 4				July 5			
	Belle	Elberta	Hale	S. Haven	Belle	Elberta	Hale	S. Haven
Raffensperger Orchard								
Dritomic sulfur	0	0	0		13.5	4.6	4.2	
Oil emulsion	.5	.3	.8		13.1	11.7	9.4	
Oil emulsion—Koloform	4.3	4.8	1.1		12.4	10.4	8.4	
Oil emulsion—dritomic sulfur	1.9	3.3	2.2		8.1	16.2	6.1	
Oil emulsion—flotation sulfur	3.7	3.3	2		15.1	12.2	5.2	
Oil emulsion—self-boiled lime sulfur	30.8	23	17		36.9	29.8	28.1	
Lott Orchard								
Self-boiled lime sulfur	0	0	0	0	6.7	2.3	1.8	1.8
Oil emulsion	.3	.2	.4	0	6	5.8	4.9	5
Oil emulsion—Koloform	.6	1.7	1.8	1.6	6.3	4.3	4.3	6.2
Oil emulsion—dritomic sulfur	.4	1.1	.5	.5	5.1	3.1	4.1	4
Oil emulsion—flotation sulfur	.5	1	1	.4	8.2	8.1	9.6	8.1
Oil emulsion—self-boiled lime sulfur	16.6	10.9	13.7	17.4	18.2	11.8	14.1	19

orchard. No lead was used in the Lott orchard. Zinc sulfate was added to dritomic sulfur on the rest of the Raffensperger orchard but was not used in the oil–dritomic sulfur block.

Table 2.—Percentage of defoliation (based on 500 leaves) resulting from sprays applied to peach, 1935.

Treatment[1]	June 4				July 5				Average Growth *inches*
	Belle	Elberta	Hale	S. Haven	Belle	Elberta	Hale	S. Haven	
Raffensperger Orchard									
Dritomic sulfur	.1	.2	.2		8.4	7.9	7.8		3.1
Oil emulsion	.5	.3	.6		5.5	4.1	9.5		3.5
Oil emulsion—Koloform	.3	2.5	1.7		9.9	5.3	14.2		3
Oil emulsion—dritomic sulfur	.8	1.2	2.4		7.6	6.2	16.4		3.4
Oil emulsion—flotation sulfur	2.9	2.1	2.6		9.2	5.8	12.7		3.2
Oil emulsion—self-boiled lime sulfur	4.1	1.3	1.9		4.5	4	3.9		3.2
Lott Orchard									
Self-boiled lime sulfur		0	0	0	3.9	3.9	2.6	3.6	7.8
Oil emulsion		.4	.4	0	42.3[2]	57.5[2]	47.4[2]	40.1[2]	9.4
Oil emulsion—Koloform		4	4.7	4	6.2	5.8	9	4.5	9.1
Oil emulsion—dritomic sulfur		4.2	5.5	4	5.8	5	8.1	3.4	8.4
Oil emulsion—flotation sulfur		3.3	3.8	4.2	5	4.5	9	4.9	8.5
Oil emulsion—self-boiled lime sulfur		2.8	2.8	2.3	2.1	2.9	2.8	2.3	8.6

Both orchards showed evidence of low vitality resulting from several dry seasons and two winters of freezing weather. The weakened condition of these orchards was manifested by retarded growth in the spring of 1935 and a tendency for all the trees to lose foliage, especially the basal

[1] 1.7 per cent actual oil by volume used in all oil and oil-sulfur blocks.
[2] Apparently due to concentrated lime sulfur left in spray tank.

leaves. The Raffensperger orchard received 2 pounds of cyanamid per tree in the fall of 1934 while the Lott orchard received 5 pounds of nitrate of soda per tree in the spring of 1935. Considerable difference in the growth of these orchards will be noted later. The oils were given a thorough trial under rather extreme conditions.

The sulfurs were added at the rate of 10 pounds of koloform, 5 pounds dritomic, 10 pounds flotation and 16 pounds flowers of sulfur, in the self-boiled mixture, to 100 gallons of the diluted oil emulsion.

Slight foliage injury and some defoliation is evident in all blocks and varieties, including the regular orchard treatment where no oil was used. It should be remembered that the first application was made in both orchards at the time of the shuck fall when the foliage was tender and long before it would normally be necessary to apply summer oils for red spider or summer broods of the terrapin scale.

With the exception of the straight oil-emulsion block in the Lott orchard and the two oil–self-boiled lime sulfur blocks, foliage injury and defoliation were not more serious than injuries in the rest of the orchard. The excessive defoliation in the straight oil block in the Lott orchard cannot be entirely explained. It is obvious that it was not due to the oil because this plot shows a low per cent of defoliation on June 4 following the shuck-fall application. Furthermore, heavy defoliation did not occur in the Raffensperger orchard where the vitality of the trees was apparently lower. It is believed that the injury was due to a small amount of concentrated lime sulfur left in the tank from previous spraying.

Foliage injury in the oil–self-boiled lime sulfur blocks was no doubt due to heavy applications of sulfur. These plots received 16 pounds of sulfur and 16 pounds of lime to 100 gallons of spray material, two or three times as much sulfur as the other blocks received. This injury can probably be eliminated by reducing the amount of sulfur. In spite of the high per cent of foliage injury in these blocks, defoliation was less than in the rest of the orchard. Belle of Georgia and Elberta showed the greatest amount of folliage injury, while Hale showed the greatest amount of defoliation.

The foliage injury was not as serious as the figures indicate because the smallest discolored spot was counted as an injured leaf. The basal leaves of all the trees, including the blocks that did not receive oil, fell during the summer. These leaves dropped earlier in the season in the oil blocks. No fruit injury was detected in any of the blocks in either orchard.

A number of soaps and oil emulsions, with and without wettable sulfurs, were tested on a small scale to determine their effect upon Elberta foliage. These materials were applied to 12-year-old trees between May 9 and September 19 with a hand sprayer and about 150 pounds pressure. Peach foliage hardens considerably after July and a fair test of the resistance of foliage to spray injury cannot be secured after this time. No defoliation resulted from the application of any of the materials but severe injury resulted from sulfonated corn oil at the rate of 1.5 per cent actual oil. Sulfonated corn oil was also applied to apple, resulting in severe burning on Stayman and McIntosh and slight injury to York

Imperial. In comparing lead treatments, Chipman's powdered acid arsenate of lead and Rex powdered basic arsenate of lead were used. The following materials were also tested: California Spray Chemical Co., Orthol K, 83 per cent oil; National Oil Products Co., paraffin-wax emulsion 1810, 20 per cent wax; soluble fish-oil soap, 25 per cent soap; sulfonated corn oil, 80 per cent oil; Crystal Soap Chemical Co., coconut-oil–potash soap (C.P.O.), 40 per cent soap; linseed-oil–potash soap, 50 per cent soap; corn-oil–potash soap, 50 per cent soap; B. G. Pratt Co., summer scalecide, 90 per cent oil; Beaver Remmers Graham pine-tar soap, 5 per cent.

Table 3.—Oil and soap combinations applied to Elberta peaches.

Date	No. Trees Sprayed	Material	Dilution per 100 Gals.	Active Ingredients, Per Cent by Volume	Results
May 9	2	Orthol K	2 gals.	1.66	No injury
		Koloform	10 lbs.		
		Basic lead arsenate	4 lbs.		
May 9	2	Orthol K	2 gals.	1.66	No injury
		Koloform	10 lbs.		
		Acid lead arsenate	4 lbs.		
June 14	7	Orthol K	1.8 gals.	1.52	No injury
		Koloform	10 lbs.		
July 10	3	Coconut-oil—potash soap	1.2 gals.	.47	No injury
		Koloform	10 lbs.		
July 10	3	Linseed-oil—potash soap	10 lbs.	.64	No injury
		Koloform	10 lbs.		
July 10	3	Pine-tar soap	10 lbs.		No injury
		Koloform	10 lbs.		
August 1	3	Sulfonated corn oil	1.8 gals.	1.5	93% foliage injury
August 1	3	Sulfonated corn oil	1.8 gals.	1.5	80% foliage injury, no defoliation
		Dritomic sulfur	5 lbs.		
August 9	1	Paraffin-wax emulsion	1.25 gal.	.25	No injury
August 9	1	Paraffin-wax emulsion	1.25 gals.	.25	No injury
		Dritomic sulfur	5 lbs.		
August 9	1	Orthol K	1.25 gals.	1.04	No injury
August 9	1	Orthol K	1.25 gals.	1.04	No injury
		Dritomic sulfur	5 lbs.		
September 19	2	Soluble fish-oil soap	1.87 gals.	.47	No injury
September 19	2	Soluble fish-oil soap	1.87 gals.	.47	No injury
		Dritomic sulfur	5 lbs.		
September 19	2	Summer scalecide	1 gal.	.90	36.2% foliage injury
September 19	2	Summer scalecide	1 gal.	.90	32.2% foliage injury
		Sulfocide	1 gal.		

Table 4.—Red spiders recovered from white paper placed beneath sprayed branches.

	Treatment				
	½% Orthol K	1% Orthol K	½% Paraffin-wax emulsion	½% Corn-oil–potash soap	Check
Alive	17	11	25	15	29
Dead	229	224	77	232	19

Red spider, *Paratetranychus pilosus*.—It is difficult to get a fair index of red spider control. The most uniform results were obtained from laboratory tests, spraying four to six branches, at least 4 feet long, with a hand sprayer and 150 pounds pressure. Counts were made of the number of spiders living three or four days after the application. Apple leaves shrivel too rapidly for this work but peach foliage placed in water will keep fresh for at least seven days. Dead spiders fall rapidly from the leaves, as is evident in table 4. White paper was placed beneath the

branches immediately after they were sprayed and counts of live and dead spiders were made 24 hours later.

The preceeding table does not give an idea of control because no account is taken of the number of living spiders remaining on the foliage. In the check and the paraffin-wax emulsion test, a large number of living spiders remained on the foliage. This illustrates that it is hopeless to bring branches from a sprayed orchard and make counts of dead spiders. In the following tests only living spiders were counted. The per cent kill was figured from the total number of spiders on the checks on the days the applications were made. Five sets of checks were used, corresponding to the five days on which the sprays were made.

Table 5.—Laboratory tests with soaps and oil emulsions against red spider.

Material	Active Ingredients, Per Cent by Volume	No. Live Red Spiders	Dead Spiders, Per Cent
Summer-oil emulsion	.5	1380	55.4
Paraffin-wax emulsion	.25	1363	55.9
Check, August 19		3096	0
Summer-oil emulsion	.5	261	74.6
Summer-oil emulsion	1	61	94
Summer-oil emulsion, wettable sulfur added	1	69	91.3
Paraffin-wax emulsion	.25	489	52.4
Check, August 27		1028	0
Paraffin-wax emulsion	2	76	92.2
Linseed-oil—potash soap	2	8	99.2
Summer scalecide	.9	316	74.1
Check, September 23		1269	0
Paraffin-wax emulsion	2	243	80
Corn-oil—potash soap	2	10	99
Coconut-oil—potash soap	2	28	97.8
Soluble fish-oil soap	2	20	97.6
Check, September 27		805	0
Corn-oil—potash soap	2	8	97.6
Linseed-oil—potash soap	2	14	95.9
Coconut-oil—potash soap	2	12	96.4
Soluble fish-oil soap	2	24	92.9
Summer scalecide[4]	.9	75	78
Check, October 1		342	0

The summer eggs of red spiders are easier to kill than the nymphs or adults. One-quarter per cent of paraffin-wax emulsion gave 99.3 per cent kill and .9 per cent summer scalecide gave 99 per cent kill. The nymphs, on the other hand, are more difficult to kill than the adults because they are protected beneath mats of silk while the adults usually run about the leaves unprotected.

Table 6.—Laboratory tests with soaps and oil emulsions against red spider.

Material	Active Ingredients, Per Cent by Volume	Test 1 Per Cent Dead	Test 2 Per Cent Dead
Summer oil emulsion	.5	55.4	74.6
Summer oil emulsion	1	94	91.3
Paraffin wax emulsion	.25	55.9	52.4
Paraffin wax emulsion	2	92.2	80
Corn-oil—potash soap	2	99.2	97.6
Linseed-oil-potash soap	2	99.2	95.9
Coconut-oil—potash soap	2	96.4	97.8
Soluble fish-oil soap	2	92.9	97.8
Summer scalecide[4]	.9	74.1	78
Five checks		0	0

Terrapin scale, *Lecanium nigrofasciatum*.—A limited number of tests were made with soaps and oil emulsions against the terrapin scale of peach. These figures are not conclusive but indicate that soaps and oils

[4] Not recommended for red spider control without addition of sulfocide.

are effective against young scales on peach foliage. Linseed-oil—potash soap is especially toxic to young scales. The high mortality in the check is due to various summer applications of sulfur.

Table 7.—Tests against the terrapin scale.

Treatment	Active, Ingredients, Per Cent by Volume	No. Scales Counted	Per Cent Kill
	Larvae on peach leaves		
Orthol K	.5	543	97.6
Orthol K	1	547	99.8
Check		552	31.8
	Mature scales on peach shoots		
Linseed-oil—potash soap	2	70	100
Paraffin-wax emulsion	2	250	47
Summer scalecide	.9	190	44
Check		160	0

Conclusions.—While considerable injury occurred where oil emulsions were applied to peach foliage, it was not more serious than the injury in parts of the orchard where no oils were used.

The combination of sulfur with oil emulsions did not increase the amount of injury, except in the self-boiled sulfur blocks where defoliation was due to excessive sulfur.

One and one-half and 2 per cent oil emulsions, as well as vegetable and animal-oil–potash soaps, gave high toxicity against red spider and terrapin scale.

CODLING MOTH EXPERIMENTS IN NEW JERSEY IN 1935[1]

Byrley F. Driggers, *New Jersey Agricultural Experiment Station*[2]

The orchard spraying experiments for codling moth control on apples during 1934 were carried on in the two-brooded Glassboro area. In these experiments, the results of which were published in the Journal,[3] a number of fixed-nicotine compounds were tested in comparison with the lead arsenate–lime–milk schedule and with the lead arsenate–summer-oil schedule. The following are some of the conclusions drawn from the work in 1934. (1) Tank-mixed bentonite sulfur with nicotine sulfate and sulfo-ammonium soap as a spreader produced more clean fruit than the lead arsenate–lime–milk schedule. (2) The proprietary fixed-nicotine compounds tested were less effective than the tank-mixed nicotine compounds. (3) The fixed-nicotine compounds tended to reduce stinging as compared with the lead arsenate sprays; on the other hand, lead arsenate, particularly when combined with summer oil, was more effective in reducing the number of worms reaching maturity. (4) Little foliage injury was produced on the fixed-nicotine plots, whereas the lead arsenate plots were severely burned. (5) Spraying with tank-mixed bentonite sulfur and nicotine on winter apples during August left a visible residue which was objectionable, particularly on apples destined for export.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

[2] The writer was assisted by Mr. W. J. O'Neill, a graduate student in entomology, in carrying out the spraying tests and in collecting the data.

[3] Jour. Econ. Ent. 28(1):162. Feb. 1935.

The 1935 experiments were planned for the purpose of testing several new proprietary fixed-nicotine products developed by the Tobacco By-Products and Chemical Corporation and found promising in preliminary tests carried on in their laboratories. The new products were to be tested on several varieties of apples to determine whether they were injurious to fruit or foliage and to determine their effectiveness in controlling codling moth. Another objective was to discover a spreader more suitable than sulfo-ammonium soap for use with the tank-mixed bentonite and nicotine. Still another objective was to test the effect of adding lime to the tank-mixed bentonite sulfur and nicotine for the purpose of making easy the removal of the residue. It was also planned to test the recommended codling moth schedule of bentonite sulfur (or bentonite) with nicotine, followed by nicotine tannate, or nicotine and oil.

Description of plots and treatments.—Twelve plots were laid out in a block of Stayman-Winesap apples located in the orchard leased by the Department of Entomology. This block of trees was used in 1933 and 1934 for the experimental work of those years. Each plot was made up four trees wide and four deep for a total of 16 trees. A second series of plots was laid out in a block of Rome Beauty trees in the same orchard. Each plot consisted of two rows of three trees each.

The Staymans in the test plots set a light crop of fruit in 1935 for the third successive year, due to poor pollination conditions at the time they were in bloom. The Rome Beauty plots were small and the trees rather uneven in regard to vigor and set of fruit. Therefore it was decided to lay out a third series of plots in another orchard on a third variety made up of trees carrying a full and uniform crop. A block of Smokehouse trees 14 trees wide and 35 trees deep was selected in a nearby orchard. In the center of this block the writer laid out 12 plots of nine trees each in such a manner that the series of 12 plots were surrounded on three sides by Smokehouse trees receiving the regular lead arsenate–lime–milk cover sprays.

The plot arrangement as outlined allowed for the testing of each of 12 treatments once on each of three varieties of apples. One plot in each variety was used for the lead arsenate–lime–milk schedule and one for the lead arsenate–summer-oil schedule. These two schedules served as checks against which 10 different nicotine combinations were tested. All plots on all three varieties were sprayed the same at the delayed dormant, prepink, pink and petal-fall stages.[4] Ten days after the petal-fall application the different plots began receiving the different treatments. A fungicide consisting of either bentonite sulfur or flotation sulfur was used in the first three cover sprays on all plots except plot 3 (lead arsenate–summer oil) and plot 5 (Black Leaf 155T). Coposil was the fungicide used on these two plots.

The details of plot treatments are set forth in table 1. Plots 1 and 2 were sprayed the same during the first brood with tank-mixed bentonite sulfur, nicotine and soap. On second brood lime was added to the mixture on plot 2 to determine if this material would aid in the removal of the bentonite sulfur. Dry skim milk was used as the spreader on plot 2

[4] Apple Spray Calendar. N. J. Ag. Exp. Sta. Circ. 210.

on second brood. The Black Leaf 155T used on plot 5 showed up so poorly at the end of first brood that this material was discontinued and a combination of lead arsenate, bentonite sulfur, lime and nicotine was used on this plot on second brood. Plots 9, 10 and 11 were sprayed the same during first brood except for the type of spreader used. Sulfo-ammonium soap was used on plot 9, Aresket on plot 10 and dry skim milk

Table 1.—Spray materials used during first and second broods on Stayman, Rome Beauty and Smokehouse apples. All plots received four cover sprays for the first brood in June and five sprays for the second brood in July and August, with the exception of Smokehouse apples, which received four cover sprays for the second brood.

Plot No.	Materials and Amounts per 100 Gallons	
	First Brood	*Second Brood*
1	Bentonite sulfur 6 lbs., Black Leaf 40 1 pt., sulfo-ammonium soap ½ pt.	Same as first brood except last spray: tannic acid 3 pts., free nicotine 1 pt.
2	Bentonite sulfur 6 lbs., Black Leaf 40 1 pt., sulfo-ammonium soap ½ pt.	Bentonite sulfur 6 lbs., Black Leaf 40 1 pt., lime 4 lbs., milk ½ lb. except last spray: nicotine tannate.
3	Lead arsenate 4 lbs., lime 2 lbs., fluxit ½ lb. in 1 spray. Lead arsenate 2 lbs., lime 2 lbs., fluxit ½ lb., Orthol K oil 3 qts. in 3 sprays.	Lead arsenate 2 lbs., fluxit ½ lb., Orthol K oil 3 qts. in 1 spray. Lead arsenate 3 lbs., lime 6 lbs., fluxit ½ lb. in 4 sprays.
4	Black Leaf 155B 6 lbs.	Black Leaf 155B 6 lbs.
5	Black Leaf 155T 4 lbs.	Lead arsenate 3 lbs., bentonite sulfur 3 lbs., lime 3 lbs., milk ½ lb., Black Leaf 40 ½ pt.
6	Lead arsenate 3 lbs., lime 3 lbs., milk ½ lb.	Lead arsenate 3 lbs., lime 6 lbs., milk ½ lb.
7	Black Leaf 155A 6 lbs.	Black Leaf 155A 6 lbs., lime ⅛ ounce.
8	Nico-Zin 2½ lbs.	Nico-Zin 2½ lbs.
9	Bentonite sulfur 6 lbs., Black Leaf 40 1 pt., sulfo-ammonium soap ½ pt. in 3 sprays. Bentonite 4½ lbs., Black Leaf 40 1 pt., soap ½ pt. in 1 spray.	Bentonite 4½ lbs., Black Leaf 40 1 pt., sulfo-ammonium soap ½ pt. in 3 sprays. Tannic acid 3 pts., free nicotine 1 pt. in 2 sprays.
10	Bentonite sulfur 6 lbs., Black Leaf 40 1 pt., Aresket ½ lb. in 3 sprays. Bentonite 4½ lbs., Black Leaf 40 1 pt., Aresket ½ lb. in 1 spray.	Bentonite 4½ lbs., Black Leaf 40 1 pt., Aresket ½ lb. in 3 sprays. Tannic acid 3 pts., free nicotine 1 pt. in 2 sprays.
11	Bentonite sulfur 6 lbs., Black Leaf 40 1 pt., milk ½ lb. in 3 sprays. Bentonite 4½ lbs., Black Leaf 40 1 pt., milk ½ lb. in 1 spray.	Bentonite 4½ lbs., Black Leaf 40 1 pt., milk ½ lb in 3 sprays. Orthol K oil 3 qts., Black Leaf 40 ½ pt. in 2 sprays.
12	Black Leaf 155C 6 lbs., fish oil 1 pt.	Black Leaf 155C 6 lbs., fish oil 1 pt.

on plot 11. These three plots were sprayed with bentonite until August 10, then plots 9 and 10 received two additional sprays of nicotine tannate. Plot 11 was sprayed with oil and nicotine after the bentonite was discontinued.

Table 2.—Percentage of apples injured by codling moths at end of first brood.[5]

Plot No.	Per Cent Injured Fruit			Plot No.	Per Cent Injured Fruit		
	Stayman	Rome	Smokehouse		Stayman	Rome	Smokehouse
1	25.5	12.2	7.8	7	13.8	20	5
2	20	11.7	6.2	8	14	12	6.5
3	4.5	3.2	5.2	9	6.5	14	5
4	6.1	9	4.2	10	8.8	8	4.2
5	25.3	13.5	5.5	11	10.3	6	4
6	23	21.2	6.5	12	15.8	8.2	4.2

Methods used to determine results.—The following methods were used to determine the results of the different treatments. At the end of first-brood entry a number of apples were examined at random in each plot on each of the three varieties. On the Stayman plots 600 apples were examined, on Rome 400 and on Smokehouse 1200. The counts were made at random on four or five trees in each plot. No effort was made to differentiate between "stung" and "wormy" fruit.

[5] Six hundred Stayman apples examined, 400 Rome Beauties, 1200 Smokehouse.

Beginning the first of August on Stayman and the first of July on Smokehouse, the writer collected all the drops every week or 10 days until harvest on five trees in each Stayman plot and on three trees in each Smokehouse plot. These were scored as "stung," "wormy" or "clean." At harvest all the fruit on the marked trees in each plot was examined and scored as "stung," "wormy" or "clean." The "drops" were added to the harvested fruit in the final tabulation of data. No drops were examined on the Rome and lack of time prevented an examination of all plots at harvest on this variety. Five bushels of picked fruit were examined at harvest from each of plots 3, 4, 6 and 11 on the Rome.

Table 3.—Percentages of clean and codling moth-injured Smokehouse apples at Glassboro. All fruit on three trees examined at harvest and dropped fruit included from July 1.

Plot No.	Treatment[4]	Total Apples	Per Cent Apples Injured			Per Cent Uninjured
			Stung	Wormy	Total	
1	Bentonite sulfur, Black Leaf 40	14197	17.1	21.5	38.6	61.2
2	Bentonite sulfur, Black Leaf 40, lime added for second brood.	13758	16.5	28.9	45.4	54.6
3	Lead arsenate, summer oil	15582	25.5	6.4	31.9	68.1
4	Black Leaf 155B	12460	13.3	12.4	25.7	74.3
5	Black Leaf 155T	12017	29.8	29.6	59.4	40.6
6	Lead arsenate, lime, milk	17240	32.6	12.2	44.8	55.1
7	Black Leaf 155A	17312	14.4	21.5	35.9	64.1
8	Nico-Zin	12103	18.2	13.2	31.4	68.6
9	Tank mixture, soap	13097	17	22.1	39.1	60.9
10	Tank mixture, Aresket	13028	17.2	17.6	34.8	65
11	Tank mixture, milk	18058	16.6	13.8	30.4	69.5
12	Black Leaf 155C, fish oil	13870	10.7	12.7	23.4	76.4

Another method used to compare the nicotine plots was to analyze the foliage for nicotine before and after each spray. Samples of leaves from the Stayman plots only were collected, as previously described,[3] and forwarded to the laboratories of the Tobacco By-Products and Chemical Corporation for analysis.

Table 4.—Percentages of clean and codling moth-injured Staymen apples at Glassboro. All fruit on five trees examined at harvest and dropped fruit included from August 1.

Plot No.	Treatment[4]	Total Apples	Per Cent Apples Injured			Per Cent Clean
			Stung	Wormy	Total	
1	Bentonite sulfur, Black Leaf 40	2482	26.2	19.5	45.7	54.2
2	Bentonite sulfur, Black Leaf 40, lime added for second brood.	2118	32.1	18	50.1	49.7
3	Lead arsenate, summer oil	1012	47.1	4.5	51.6	48.3
4	Black Leaf 155B	1914	18.1	8.2	26.3	73.5
5	Black Leaf 155T	1781	60.5	29.9	90.4	9.5
6	Lead arsenate, lime, milk	1781	63.5	24	87.5	12.4
7	Black Leaf 155A	2036	34.6	44.7	79.3	20.6
8	Nico-Zin	1477	40.5	25	65.5	34.4
9	Tank mixture, soap	1137	27.4	12.9	40.3	59.6
10	Tank mixture, Aresket	1114	30.9	10.7	41.6	58.3
11	Tank mixture, milk	1638	31.9	11.1	43	56.9
12	Black Leaf 155C, fish oil	864	24.5	19.2	43.7	56.2

In addition to the taking of biological and chemical data, the writer made frequent observations throughout the season to determine if foliage or fruit injury occurred on any of the plots. Observations on the type of coverage obtained with the different spreaders were also made, together with observations on the ease of removal of residue at harvest.

[4] For complete details of treatments see table 1.

Tabulation of results.—From July 5 to 12 first-brood codling moth injury was determined on all plots as previously described. The results are set forth in table 2.

Fruit on the three marked trees in each of the Smokehouse plots was harvested and examined in September. The fruit on the five trees in the Stayman plots was harvested and examined in October. The results from examination of the picked fruit plus the accumulated drop fruit on the two sets of plots are set forth in tables 3 and 4. The counts from four plots in the Rome are set forth in table 5.

Table 5.—Percentages of clean and codling moth-injured Rome Beauty apples at Glassboro.

Plot No.	Treatment[6]	Total Apples[7]	Per Cent Apples Injured			Per Cent Clean
			Stung	Wormy	Total	
3	Leaf arsenate, oil	940	48.9	8.8	57.7	42.3
4	Black Leaf 155B	856	22.2	9.8	32	68.3
6	Lead arsenate, lime	898	47.2	47	94.2	5.8
11	Black Leaf 40, bentonite[8]	1100	41.7	20.3	42	58

Foliage sampling on the nicotine plots was begun before the third cover spray on June 14. Samples before and after each cover spray thereafter were made to August 27. The results, set forth in tables 6 and 7,

Table 6.—Amount of nicotine on Stayman foliage sprayed with different nicotine compounds. Samples taken before and after each spray application; amounts shown are mgs. per square centimeter $\times 10^{-3}$.

Spray Date	Plot Number								
	1	*2*	*4*	*5*	*7*	*8*	*9*	*10*	*11*	*12*
June 14										
Before	4.36	2.86	1.24	.3	.63	1.01	2.98	3.03	4.53	1.64
After	7.02	8.94	5.95	3.12	3.3	3.91	8.5	7.78	9.75	6
June 25										
Before	2.12	2.16	.78				3.05	3.32	3.87	1.21
After	8.76	7.25	4.57	2.61	2.79	3.45	11.68	11.87	14.02	5.02
July 17										
Before	5.13	4.05	1.24	.23	.03	1.23	6.83	8.86	7.62	1.85
After	13.08	5.19	4.92	4.39	4.55	3.19	12.6	12.98	13.91	4.6
July 26										
Before	6.08	.79	1.41	.23	.44	1.68	6.78	7.15	8.07	1.52
After	10.03	3.42	4.72		3.67	3.42	13.74	13.38	15.02	5.02
August 8										
Before	6.83	.83	1.98		.9	.93	8.33	9.72	9.44	1.24
After	12.54	3.38	5.58	.61	5.11	2.94	13.57	16.03	14.3	5.98
August 17										
Before	8.17	.15	1.24	.24	1.2	.6	9.46	7.85	7.78	1.31
After	10.88	2.32	5.08	.06	5.86	4.59	13.58	12.54	12.08	3.78
August 27										
Before	8.97	.87	3.69		1.54	2.16	10.9	14.07	9.63	2.29
After	15.2	8.67	6.73	.74	5.02	3.68	16.54	21.07	12.66	5.52

show the amount of nicotine in milligrams per square centimeter of apple foliage. Table 7 shows the average amount of nicotine for seven samples taken before spraying and for seven samples taken immediately after spraying.

Discussion of Results

Control, first brood.—A study of the data in table 2 shows that at the end of first-brood entry, of the two arsenate of lead schedules, oil–lead arsenate (plot 3) was superior to lime–lead arsenate (plot 6). None of the fixed-nicotine compounds equalled the oil–lead arsenate but most of

[7] Five bushels of harvested fruit were examined from each plot.
[8] Last two sprays oil-nicotine.

them were equal or superior to the lime—lead arsenate treatment. Black Leaf 155T (plot 5) and Black Leaf 155A (plot 7) appeared to be stopping but few of the larvae. Examination of the analysis figures up to the end of first brood indicated that practically all the nicotine was disappearing from plots 5 and 7 during the 10-day intervals between sprays, therefore the treatments on these two plots were changed during second brood. The showing of Black Leaf 155B (plot 4) at the end of first-brood entry indicated that this material was almost as effective as the oil–lead arsenate treatment and definitely superior to the lime–lead arsenate.

Table 7.—Amount of nicotine on Stayman foliage, samples taken before and after spraying. Amounts shown are mgs. per square centimeters $\times 10^{-3}$ and represent average of seven samples taken from June 14 to August 27.

Plot No.	Treatment[6]	Before Spraying	After Spraying
1	Bentonite sulfur, nicotine	5.95	11.07
2	Bentonite sulfur, nicotine, lime	1.67	5.6
4	Black Leaf 155B	1.65	5.36
5	Black Leaf 155T	.17	1.65
7	Black Leaf 155A	.68	4.47
8	Nico-Zin	1.09	3.6
9	Tank mixture, soap	6.9	12.89
10	Tank mixture, Aresket	7.71	13.66
11	Tank mixture, milk	7.28	13.15
12	Black Leaf 155C, fish oil	1.58	5.13

Control, harvested fruit.—A study of the data in tables 3, 4 and 5 will show that of the 12 spray treatments the Black Leaf 155B treatment produced the highest percentage of clean fruit, with 74.3 per cent clean in the Smokehouse, 73.5 per cent clean in the Stayman and 68.3 per cent clean in the Rome. Oil–lead arsenate (plot 3), tank-mixed bentonite sulfur, nicotine and soap (plot 1), the three tank-mixed bentonite–nicotine plots with different spreaders (plots 9, 10 and 11), the Black Leaf 155C with fish oil (plot 12) all averaged between 55 and 70 per cent clean fruit. The standard lead arsenate–lime (plot 6) finished the season with 55 per cent of the fruit clean on the Smokehouse variety and only 12.4 per cent and 5.8 per cent clean on Stayman and Rome.

If we examine the type of codling moth injury found on the different plots it is clear that the oil–lead arsenate treatment (plot 3), with 6.4 per cent wormy in the Smokehouse, 4.5 per cent in Stayman and 8.8 per cent in Rome, was the best of the 12 treatments in respect to preventing entry. Next to the oil–lead arsenate, the Black Leaf 155B treatment (plot 4) came through the season with the smallest percentage of wormy fruit, with 12.4 per cent, 8.2 per cent and 9.8 per cent respectively on Smokehouse, Stayman and Rome. The third best treatment was the tank-mixed bentonite–nicotine–milk finished off with oil–nicotine (plot 11) which had 13.8 per cent, 11.1 per cent and 20.3 per cent wormy on the three varieties. An examination of the figures dealing with the percentage of stung apples shows that the nicotine treatments as a group were superior to either lead arsenate–lime or lead arsenate–oil in reducing stinging. Black Leaf 155B (plot 4) had 13.3 per cent, 18.1 per cent and 22.2 per cent stung fruit on Smokehouse, Stayman and Rome, compared to 25.5 per cent, 47.1 per cent and 48.9 per cent for oil–lead arsenate and 32.6 per cent, 63.5 per cent and 41.7 per cent for lead arsenate–lime, on the same varieties.

Nicotine deposited and retained.—The data in tables 6 and 7 show that the tank-mixed bentonite sulfur (or bentonite) with nicotine (plots 1, 9, 10 and 11) deposited relatively a large amount of nicotine per unit area of leaf surface. The average loss of nicotine between sprays on these plots was roughly 50 per cent. The sulfo-ammonium soap, Aresket and milk used as spreaders show no significant differences in the amount of nicotine deposited and retained. What differences there were appeared to favor the milk and Aresket over the soap. None of the proprietary nicotine compounds either deposited or retained as much nicotine as the tank-mixed materials. The Black Leaf 155T formula (plot 5) and the Black Leaf 155A formula (plot 7) were so poor in maintaining a nicotine coverage and preventing larval entry that these treatments were modified during second brood. The addition of 4 pounds of lime to the tank-mixed bentonite sulfur–nicotine on plot 2 during second brood caused an immediate drop in the amount of nicotine deposited and retained on this plot. That the codling moth injury in this plot did not increase materially with the loss of nicotine may have been due to the direct kill of the moths by the free nicotine released at the time the sprays were applied, as reported by Hough.[9]

The nicotine analysis figures for the Black Leaf 155B formula (plot 4) are interesting when related to the type of coverage produced and the resulting control obtained. It will be seen that roughly twice as much nicotine was deposited on the tank-mixed plots 1, 9, 10, and 11 as was deposited on plot 4. Furthermore, the analysis shows that during the interval between sprays approximately three times as much nicotine was retained on plots 1, 9, 10 and 11 as was retained on plot 4. In spite of these facts the codling moth control on plot 4 was superior to the control on the tank-mixed plots. Looking for an explanation, the writer observed that in the tank-mixed bentonite sulfur (or bentonite) the deposit of spray obtained on the fruit was smooth, hard and difficult to remove even by vigorous brushing or rubbing. On the other hand, the deposit obtained with the Black Leaf 155B was a loose, oily appearing powder which was readily removed by wiping or brushing. At the same time this deposit appeared to resist removal by rains to a marked degree. It is believed that recently hatched larvae, crawling over the loose powdery deposit typical of Black Leaf 155B, obtain a lethal dose of nicotine (probably by contact) with less nicotine per unit of surface area than is required by the tank-mixed products which bind the nicotine more firmly to the fruit or leaf surfaces.

Foliage and fruit injury.—A careful check of foliage and fruit injury was made on all plots throughout the season. The Black Leaf 155B (plot 4) and the Nico-Zin (plot 8) formulas carried zinc as one of the constituents. It was thought that the zinc would probably produce injury, particularly in the Nico-Zin formula. During the middle of June, following the first two cover sprays, a rather severe yellowing and dropping of leaves was observed on Rome sprayed with the Nico-Zin. No similar injury was observed on the Stayman and Smokehouse at that time. How-

[9] Jour. Econ. Ent. 27(5): 1102. Oct. 1934.

ever, toward the end of June approximately a third of the apples on the Nico-Zin Smokehouse plot fell off. Such a drop of fruit did not occur on any of the other Smokehouse plots nor was it observed on the Nico-Zin plots in the Stayman and Rome. Yellowing of leaves followed by shedding was observed on Stayman sprayed with the Nico-Zin formula during July, August and September. The same was observed on Rome during August and September.

No foliage or fruit injury occurred on either of the three varieties with the Black Leaf 155B formula during June, July and August. Up to the end of the summer it appeared that the zinc in this formula would not produce injury. However, on September 10 a noticeable amount of leaf yellowing and dropping was observed on the Rome plot sprayed with the B formula. During the succeeding six weeks approximately three fourths of the leaves dropped from this variety. A similar leaf-drop was observed on the Stayman plot sprayed with Black Leaf 155B about September 20. Rather heavy defoliation occurred on this variety during the succeeding six weeks.

From these observations it is clear that neither the Nico-Zin formula nor the Black Leaf 155B formula, both of which contain zinc, is a safe spray on apples. Further work with the Black Leaf 155B formula is advisable in an effort to retain its desirable physical properties and to eliminate the burning factor, which is probably the zinc.

Plots 1, 2, 5, 7, 9, 10 and 11 showed no noticeable fruit or foliage injury on either of the three varieties during the season. Plot 12, sprayed with Black Leaf 155C and a pint of fish oil, plus flotation sulfur in the first three cover sprays, showed severe foliage-burn on Stayman at the time the fish oil and sulfur was being used. Rome and Smokehouse sprayed with the same combination of materials did not have the foliage burned. The leaf-burn on Stayman was a typical oil-sulfur injury.

Approximately half of the foliage and fruit was dropped on plot 3 of the Stayman following the second and third cover sprays which contained oil. Here again the injury appeared to be due to oil and sulfur. Twenty days had elapsed from the time the last sulfur spray was applied to the first oil-lead arsenate spray. In addition rains amounting to .5 inch had fallen during the interval. Nevertheless enough sulfur residue remained so that when the oil was applied severe foliage and fruit-drop occurred. No foliage injury was observed on plot 3 in the Rome and Smokehouse.

Residue at harvest.—Three years' experience and observations have shown that fruit sprayed too near harvest with tank-mixed bentonite sulfur and nicotine or with bentonite and nicotine, with or without a spreader, is apt to carry a visible residue which detracts from its appearance. Furthermore, the residue of bentonite is difficult, if not impossible, to remove by wiping or washing. For this reason the recommendations in New Jersey in regard to tank-mixed bentonite and nicotine for codling moth control call for the use of this spray up to a certain date, after which nicotine tannate is recommended as long as entry continues. The deadline date varies with the variety, and on winter varieties is now set at July 25.

During the past season oil–nicotine was tested in comparison with nicotine tannate for the last two or three sprays following the bentonite sprays. Particular attention was paid to the finish of the fruit and some attention to the relative control. The Maiden Blush, Smokehouse, Stayman-Winesap, Winesap and Rome were the varieties under test, giving one summer variety, one fall variety and three winter varieties. Each variety was sprayed during first brood and part of second brood with bentonite sulfur (or bentonite) and nicotine. Then nicotine tannate on one plot and oil (three-quarters of a gallon)–nicotine sulfate (three-quarters of a pint) on the other plot was used at seven to 10 day intervals to finish the season. It was observed in every case that the fruit finished off with oil–nicotine had practically no visible residue at harvest, whereas the nicotine tannate showed some residue on all five varieties.

The tests on Maiden Blush were run on a large enough scale to make comparisons with lead arsenate–lime for codling moth control. Plot 1 was sprayed six times during June and July, the first four applications consisting of tank-mixed bentonite and nicotine and the last two oil and nicotine. Plot 2 was sprayed the same except that the last two applications were nicotine tannate. Plot 3 was sprayed six times during June and July with lead arsenate three pounds, lime six pounds, milk one-fourth pound, to 100 gallons. All the fruit from four trees in each of the three plots was harvested the first two weeks in August. Total codling moth injury at harvest was 16.2 per cent, 36.7 per cent and 34 per cent for plots 1, 2 and 3. Of this injury, 2 per cent were worms on plots 1 and 3 and 6 per cent worms on plot 2. The figures show a decided advantage for the plot finished off with oil–nicotine over the plot finished off with either nicotine tannate or the standard lead arsenate plot.

Summary and conclusions.—Ten different combinations of nicotine were tested in comparison with lead arsenate–lime and lead arsenate–summer oil on three varieties of apples in the two-brooded codling moth area at Glassboro. Relative codling moth control and the effect of the materials on fruit and foliage were determined. Three spreaders to be used with tank-mixture bentonite–nicotine were tested. Summer oil plus nicotine was compared with nicotine tannate in the last two or three sprays following bentonite–nicotine, both as regards codling moth control and effect on residue at harvest. The amount of nicotine deposited and retained on the foliage by the different nicotine combinations was studied.

Based on clean fruit produced at harvest, a proprietary compound of bentonite and nicotine carrying a zinc sticker (Black Leaf 155B) gave the best control of codling moth, being superior to lead arsenate–lime and lead arsenate–summer oil. It was superior to lead arsenate–lime in preventing wormy fruit but not as effective as lead arsenate–summer oil. However, severe foliage injury appeared late in the season on two varieties sprayed with Black Leaf 155B. A loose, oily, dust coating chararteristic of the B formula appeared to give control of codling moth superior to tank-mixed bentonite–nicotine carrying double or triple the amount of nicotine on foliage. Tank-mixed bentonite and nicotine com-

pared favorably with lead arsenate–lime and lead arsenate–oil in the production of clean fruit at harvest; it was superior to either lead arsenate schedule in cutting down stings but was inferior to lead arsenate–oil in preventing larval entry. The tank-mixed bentonite–nicotine had the additional advantage of producing no fruit or foliage injury. Nicotine sulfate and summer oil was found superior to nicotine tannate as a spray to follow bentonite–nicotine both for worm control and residue removal. Aresket and dry skim milk were found to be equal to sulfo-ammonium soap at a spreader for tank-mixed bentonite–nicotine. Lime added to bentonite sulfur–nicotine in the second-brood sprays aided in the removal of the residue but greatly reduced the amount of nicotine on the foliage between sprays.

EFFECT OF PROCEDURE ON PERFORMANCE OF CERTAIN INSECTICIDES RECOMMENDED FOR CODLING MOTH CONTROL

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The desirability of numerous replicates in experimental spraying for codling moth control is generally recognized. Since the extent of replication is definitely limited by the number of trees in each plot, several investigators have advocated the use of a single tree per plot. Others have insisted, on the contrary, that a marginal border of trees is necessary between plots to prevent the overlapping of treatments due to spray drift. Nine trees in a square are the minimum number that will provide such a border, records being taken from the protected tree in the center. Although a single-tree plot may be expanded by several trees, it still fails to meet these requirements.

During 1935 the effect of the procedures in question on the performance of certain insecticides recommended for codling moth control was observed under Delaware conditions, wherein close planting and strong winds continually and seriously interfere with spraying.

A block of uniform 24-year-old Jonathan apple trees, planted 30×30 feet, was divided into two adjoining sections of 225 and 25 trees, respectively. Each section was then divided into 25 plots, providing five replicates for the following insecticides: lead arsenate, calcium arsenate, Manganar, zinc arsenate and Kalo. The arrangement of the plots in each section was identical, being a doubly restricted replication within the "Latin square." There were, therefore, 25 plots of nine trees each and 25 of one tree each, fig. 1.

Identical concentrations (4 pounds per 100 gallons) and fungicides were used with each insecticide in the petal-fall application and in seven cover sprays, table 1. All plots were sprayed on the same day. The sprayer was a 300-gallon capacity Friend, operating under 250 pounds

pressure and equipped with two four-nozzle brooms (one on a tower and the other on a platform at the rear). The machine moved continuously at a slow walk, delivering eight gallons per tree.

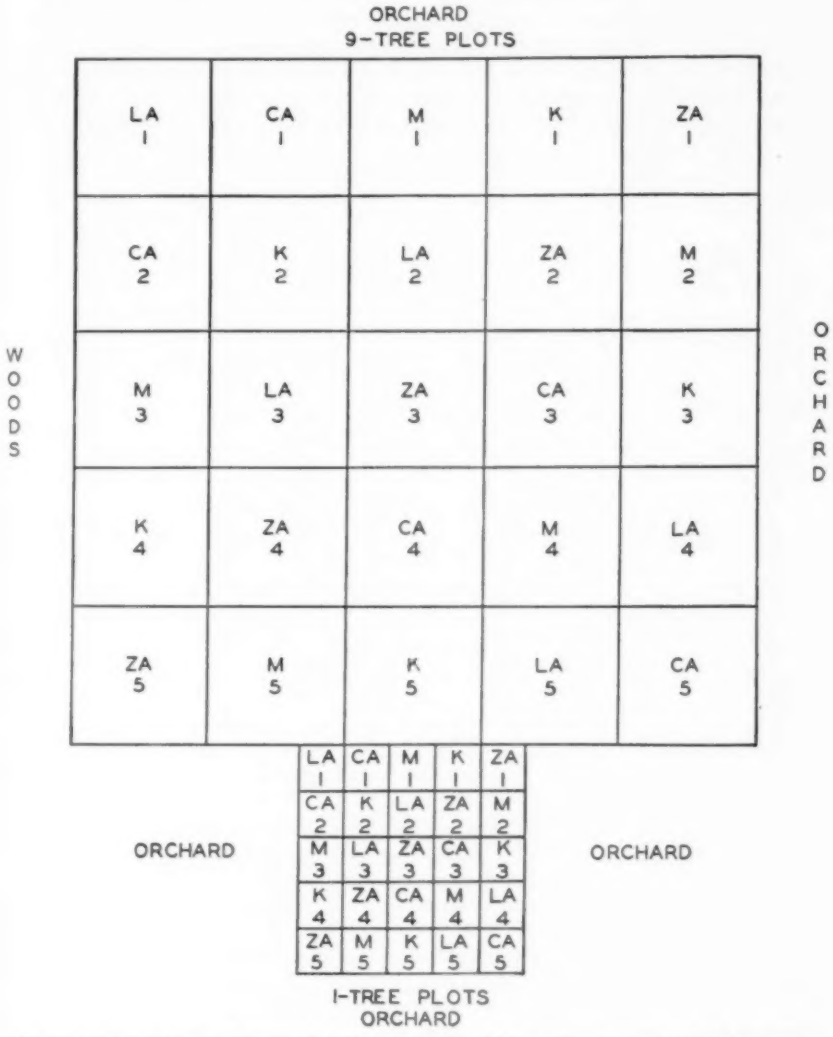

Fig. 1.—Plot Arrangement, LA, lead arsenate; CA, calcium arsenate; M, Manganar; K, Kalo; ZA, zinc arsenate.

The entire crop of all count trees (50), dropped apples included, was examined for codling moth injury, table 2.

Lead arsenate, regardless of experimental procedure, was decidedly the

most effective insecticide in protecting the fruit from codling moth attack. An average of the data from the single-tree and nine-tree replicates indicates that the remaining four compounds were effective in the following order: calcium arsenate, zinc arsenate, Kalo and Manganar.

A chemical analysis of both leaf and fruit samples from each count-tree was made in order to determine the amount of spray drift between the various plots.[1] Since only one series of plots had received spray applications containing lead, the amount of lead found was selected as a criterion of the extent of adulteration due to spray drift. A sample of 100

Table 1.—Spray program.

Date	Spray	Material per 100 Gallons	
May 8	Petal-fall	Insecticide	4 lbs.
		Flotation sulfur (paste)	10 lbs.
		Hydrated lime	5 lbs.
May 20	First cover	Insecticide	4 lbs.
		Flotation sulfur (paste)	10 lbs.
		Hydrated lime	5 lbs.
June 1	Second cover	Insecticide	4 lbs.
		Flotation sulfur (paste)	10 lbs.
		Hydrated lime	5 lbs.
June 12	Third cover	Insecticide	4 lbs.
		Flotation sulfur (paste)	10 lbs.
		Hydrated lime	5 lbs.
June 21	Fourth cover	Insecticide	4 lbs.
		Flotation sulfur (paste)	10 lbs.
		Hydrated lime	5 lbs.
July 15	Fifth cover	Insecticide	4 lbs.
		Dritomic sulfur	3 lbs.
		Hydrated lime	3 lbs.
July 30	Sixth cover	Insecticide	4 lbs.
		Dritomic sulfur	3 lbs.
		Hydrated lime	3 lbs.
Aug. 12	Seventh cover	Insecticide	4 lbs.
		No fungicide	
		Hydrated lime	5 lbs.

square inches of leaf surface was collected from each tree with a punch capable of cutting out an area of one square inch. A single leaf furnished one square-inch clipping, 25 being taken from each side of a tree two days after the fourth cover spray had been applied. A representative sample of 16 apples was reserved from each count tree at harvest. Each of these apples was washed for one minute in hot 15 per cent nitric acid.

The organic matter in the leaf samples and apple washings was destroyed by the nitric-perchloric acid method described by Gieseking, *et al.* (*2*): (40 ml. of concentrated nitric acid were added to each sample

[1] The authors are indebted to M. W. Goodwin, assistant chemist, Delaware Agricultural Experiment Station, for advice and assistance in these analyses.

which was then heated until almost dry; 10 ml. of dilute nitric acid—1 to 1—and 10 ml. of 70 per cent perchloric acid were next added; the solution was subsequently heated until colorless and almost dry; after cooling the samples were diluted with distilled water and filtered—to remove the silica—into volumetric flasks). An aliquot was taken for the determination of lead by a titrimetric-extraction method described by Wilkins, *et al.* (4). This method is sensitive to .001 mg. of lead in biological materials. Dithizone is employed first in the separation of lead from other metals and secondly in the final estimation of lead by quantitative titrimetric extraction. Known amounts of lead were accurately recovered by this method.

Table 2.—Insecticidal efficiency, summarized results.

Treatment	Plot Arrangement	Total Apples	Per Cent of Injury		
			Clean	Wormy	Stung
	1-tree	3693	68	8	24
Lead arsenate	9-tree	5724	77	7	16
Total and Averages		*9417*	*72.5*	*7.5*	*20*
	1-tree	2086	55	17	28
Calcium arsenate	9-tree	5334	50	23	27
Total and Averages		*7420*	*52.5*	*20*	*27.5*
	1-tree	4125	36	41	23
Manganar	9-tree	5624	53	24	23
Total and Averages		*9749*	*44.5*	*32.5*	*23*
	1-tree	3158	45	42	13
Kalo	9-tree	2860	51	37	12
Total and Averages		*6018*	*48*	*39.5*	*12.5*
	1-tree	2461	47	28	25
Zinc arsenate	9-tree	3635	53	25	22
Total and Averages		*6096*	*50*	*26.5*	*23.5*

Despite the smallness of the leaf and fruit samples, satisfactory results were obtained, table 3. With an average variation of one-tenth of a milligram and a maximum of four-tenths of a milligram per 100 square inches of leaf surface and an average variation of one-tenth parts per million and a maximum of three-tenths parts per million in the fruit samples between replicates of the nine-tree plots, the amount of lead found may be called consistent. Considerable and expected variations appeared in the amount of lead found in the one-tree replicates. The presence of lead on unsprayed fruit has been reported by Lynch, *et al.* (3). The lead deposits recovered from the lead arsenate plots are in agreement with results reported by Chapman, *et al.* (2).

The amount of lead recovered from the leaf samples of the single-tree replicates was definitely greater than that found in the nine-tree replicates. This increase in lead adulteration of the spray deposit can only be due to spray drift since every single-tree replicate was subject to drift, while the nine-tree replicates were protected. Although the fruit samples from the single-tree plots contained slightly more lead than those from

the nine-tree plots no marked increase of lead adulteration was found. Evidently the foliage was sufficiently dense to protect the majority of the fruit from all but direct applications of the spray. It was expected that the less effective compounds would be improved by adulteration (lead arsenate spray drift). No correlation existed, however, between the amount of lead found on the leaves in the various replicates and codling moth control. Since there was but little increase in lead adulteration

Table 3.—Amount of lead in spray deposits.

Treatment	Replicate Number	One-tree Plots			Nine-tree Plots		
		Leaves	Fruit		Leaves	Fruit	
		mg. per 100 sq. in.	*Parts per mil.*	*Per cent clean*	*mg. per 100 sq. in.*	*Parts per mil.*	*Per cent clean*
Lead arsenate	1	5.8650	13.91	81	6.8850	16.45	88
	2	8.4150	14.71	61	4.1310	14.25	80
	3	6.1936	14.13	55	6.2328	14.96	67
	4	6.9650	16.62	76	5.4570	15.84	74
	5	6.8596	17.09	67	5.1744	15.32	78
Average		*6.8596*	*15.29*	*68*	*5.5760*	*15.36*	*77*
Calcium arsenate	1	.6278	.41	64	.3953	.48	54
	2	.5383	.52	53	.4418	.40	59
	3	.6743	.46	45	.4325	.51	42
	4	1.4075	.33	53	.4508	.56	43
	5	1.2610	.63	61	.4508	.36	51
Average		*.9018*	*.47*	*55*	*.4342*	*.46*	*50*
Manganar	1	.4650	.60	32	.2790	.68	39
	2	.4704	.49	35	.3675	.45	44
	3	.8036	.44	36	.3720	.59	76
	4	.3920	.62	53	.2940	.37	45
	5	.4185	.59	25	.2790	.27	62
Average		*.5099*	*.55*	*36*	*.3183*	*.47*	*53*
Kalo	1	.4312	.42	41	.3953	.61	53
	2	.5580	.52	48	.2790	.67	28
	3	.8138	.77	40	.6075	.68	44
	4	.3920	.80	41	.2790	.68	67
	5	.3488	.79	56	.3332	.76	60
Average		*.5087*	*.66*	*45*	*.3788*	*.68*	*51*
Zinc arsenate	1	1.1172	.74	51	.5880	.76	63
	2	.6468	.72	46	.7840	.50	25
	3	.8640	.80	45	.8973	.56	49
	4	.6615	.65	41	.5115	.74	53
	5	.4900	.64	53	.5115	.83	75
Average		*.7559*	*.71*	*47*	*.6584*	*.68*	*53*

noted on the fruit, the foliage apparently prevents spray drift from having any appreciable effect on the degree of control. The effects of such a small amount of adulteration were apparently offset by the factor of location of plots within the orchard. Although the replicates were located by chance, the factor of location apparently caused the relative efficiency of the less effective compounds to vary with the different procedures. This difference in the relative efficiency of the same insecticides (with the possible exception of Manganar) was so slight as to be insignifi-

cant. The recorded spread in the degree of control between the nine-tree replicates was much greater than between the single-tree replicates, table 4. The greater variation in the nine-tree plots was not unexpected since the larger the area the greater the environmental differences encountered.

Table 4.—Variation between replicates.

Treatment	Plot Arrangement	Per Cent Clean Fruit										Spread
Lead arsenate	1-tree		81			76			67	61	55	26
	9-tree	88		80	78		74	67				21
Calcium arsenate	1-tree	64	61			53	53		45			19
	9-tree			59	54			51		43	42	17
Manganar	1-tree			53				36	35	32	25	28
	9-tree	76	62		45	44	39					37
Kalo	1-tree			56		48		41	41	40		16
	9-tree	67	60		53		44				28	39
Zinc arsenate	1-tree				53	51		46	45	41		12
	9-tree	75	63	53			49				25	50
Average	1-tree											*20*
	9-tree											*33*

Conclusions.—Lead arsenate was decidedly the most effective insecticide of those tested in protecting the fruit from codling moth attack. Calcium arsenate, zinc arsenate, Kalo and Manganar were effective in the order named.

Spray drift did not affect the relative efficiency of these insecticides when tested by the single-tree plot procedure.

Although the spray deposit on the foliage of single-tree plots was adulterated by spray drift, the fruit, however, was largely protected by the foliage from such adulteration.

Single-tree plots have the advantage of covering a small area and provide replicates, therefore, less subject to pronounced environmental differences. Single-tree plots should be enlarged, however, by one or two trees to overcome the possibility of a poor set of fruit and should be replicated a sufficient number of times to offset such a condition.

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AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

PAPER-READING SESSION, FORTY-SEVENTH ANNUAL MEETING

Pittsburgh, Pa., December 1934

CHLOROPID POPULATIONS ON PASTURE GRASSES IN KANSAS[1]

(Diptera, Chloropidae)

DONALD A. WILBUR and CURTIS W. SABROSKY, *Kansas Agricultural Experiment Station*

The insect populations of grasslands have for the most part been studied only casually. Little quantitative information is available concerning those insects present on grasses, their numerical abundance and seasonal distribution, their relationship to the grasses on which they are found and their relationship to neighboring crops. With the objective of obtaining data on these significant points, regular and standardized semiweekly collections were inaugurated and continued throughout the entire growing seasons of 1933 and 1934.[2] The grass areas studied included a native prairie grass complex, a Kentucky blue-grass pasture and an orchard and brome-grass mixture, all of which were in the animal husbandry pastures of Kansas State College. In 1930, extensive collections were made on a large series of plots of different species of grasses, but the collections were taken at 10-day intervals and did not start until the first generation of chloropid adults had emerged. The present discussion is a consideration of the flies of the dipterous family Chloropidae taken in the collections from grasses.

In these studies[3] approximately 11,300 chloropids representing 14 genera and 53 species were collected, examined and identified. The published records, corrected for misidentification, list only 26 species from Kansas. However, the state list now in preparation by the junior author records about 80 species. It is interesting to note that about three-fourths of the known Chloropidae of the state occur in a few grass plots on the college farm.

The list on p. 385 records the species of Chloropidae found in the pasture grass collections, with their numerical abundance.

Only occasional data have been published on the seasonal distribution of Chloropidae except for *Meromyza americana* (wheat stem maggot), *Oscinella frit* (frit fly) and *Chlorpisca glabra*. The seasonal distribution of 25 species taken on a Kentucky blue-grass pasture, a native prairie grass pasture and a brome and orchard-grass pasture in 1933 is shown in fig. 1. Except for an exceedingly hot and dry June and a dry May, that season is typical of the average conditions of the region. Three well-defined periods of emergence are evident; the first from April 24 to June 1,

[1] Contribution 435 from the Department of Entomology.

[2] In 1932, project 115 of the Kansas Agricultural Experiment Station, dealing with insect pests of alfalfa, was enlarged to permit the study of insects of grasses and other forage plants.

[3] Identifications of Chloropidae were made by the junior author.

the second from July 10 to August 4, and the third from August 23 through October. The numerical abundance of Chloropidae in the spring

Species	No. of Specimens
1. *Oscinella minor* (Adams)	3666
2. *Madiza cinerea* (Loew)	1951
3. *Meromyza americana* Fitch	1614
4. *Oscinella frit* (L.)	1190
5. *Oscinella cozendix* (Fitch)	1087
6. *Chloropisca glabra* (Mg.)	315
7. *Hippelates texana* Mall.	302
8. *Oscinella incerta* Beck.	266
9. *Hippelates subvittata* Mall.	160
10. *Madiza triangulata* (Beck.)	130
11. *Crassiseta nigricornis* Lw.	101
12. *Oscinella prozima* (Mall.)	97
13. *Diplotoxa pulchripes* Lw.	82
14. *Crassiseta longula* Lw.	74
15. *Hippelates pusio* Lw.	29
16. *Chlorops genarum* Becher	24
17. *Crassiseta costata* Lw.	23
18. *Hippelates pallipes* (Lw.)	22
19. *Madiza setulosa* Mall.	20
20. *Madiza quinquelineata* (Ad.)	12
21. *Anthracophaga* n. sp. near *distichliae* Mall.	12
22. *Chlorops certima* Ad.	12
23. *Crassiseta eunota* Lw.	11
24. *Dicraeus incongruus* Aldrich	9
25. *Chlorops quinquepunctata* Lw.	9
26. *Oscinella frontalis* (Tuck.)	9
27. *Ectecephala albistylum* Macq.	8
28. *Oscinella hinkleyi* (Mall.)	6
29. *Chlorops fossae* Becker	5
30. *Anthracophaga declinata* Buck	5
31. *Madiza* n. sp.	5
32. *Diplotoxa versicolor* Lw.	4
33. *Diplotoxa nigripes* Coq.	3
34. *Diplotoxa microcera* Lw.	3
35. *Chlorops rufescens* Coq.	3
36. *Chlorops* sp. near *pilosula* Beck	3
37. *Oscinella abdominalis* (Beck)	3
38. *Madiza latifrons* (Lw.)	3
39. *Oscinella* sp. near *magnipalpis* Beck	3
40. *Tricimba brunnicollis* (Beck.)	3
41. *Chlorops crocota* Lw.	2
42. *Chlorops sulphurea* Lw.	2
43. *Crassiseta nigriceps* Lw.	2
44. *Oscinella umbrosa* (Lw.)	2
45. *Elliponeura debilis* Lw.	1
46. *Chlorops melanocera* Lw.	1
47. *Hippelates nobilis* Lw.	1
48. *Hipplelates plebejus* Lw.	1
49. *Madiza* n.sp. like *O. marginalis* (Mall.)	1
50. *Madiza nigripalpis* Mall	1
Total	11,298

51. *Anthracophaga ingrata* (Will.) reared from *Muhlenbergia*.

52. *Euchlorops vittata* Mall. and 53. *E. similis* Mall. were taken in numbers (106 of the former and 10 of the latter). These are very close to Chloropidae, though placed in the Phyllomyzidae in Curran's Manual.

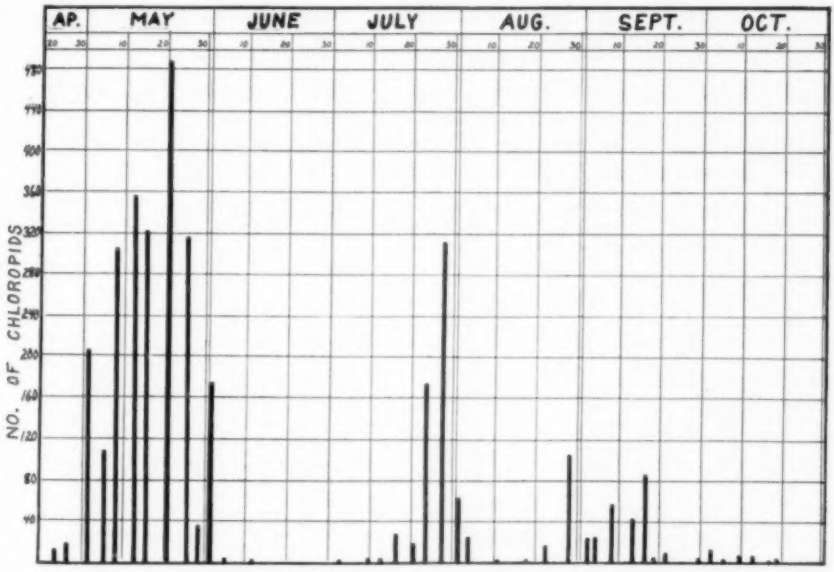

Fig. 1.—Collections of Chloropidae (except *Madiza*) for 1933.

emergence was approximately four times greater than that of the summer emergence and six times greater than that of the fall emergence. This latter period continues a full month longer than the others and may

include a partial fourth generation. Two species of the genus *Madiza* were included in a separate figure, fig. 2, because their first generation of adults appeared later than those of all other species. The greatest num-

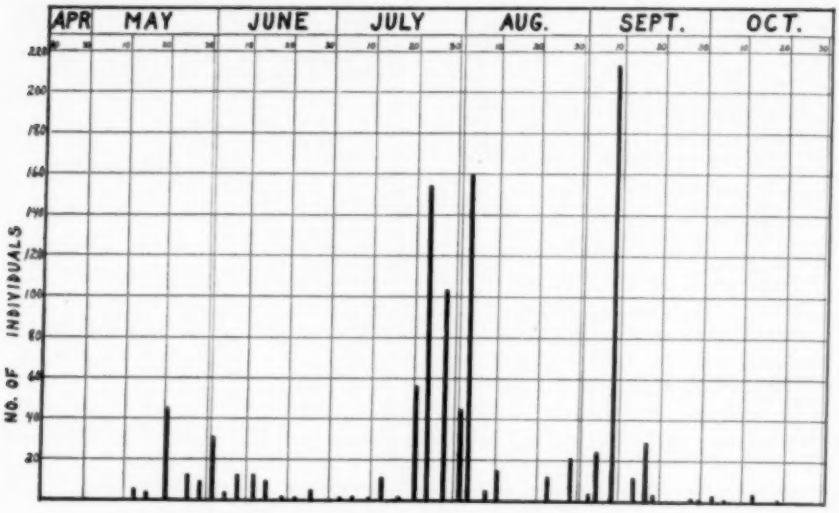

Fig. 2.—Collections of Chloropidae, genus *Madiza*, for 1933.

ber of *Madiza* appeared in the summer period. Evidence of at least three generations and perhaps a partial fourth is substantiated in unpublished collection and rearing data on *Meromyza americana* by Merle Allen at the Kansas Agricultural Experiment Station.

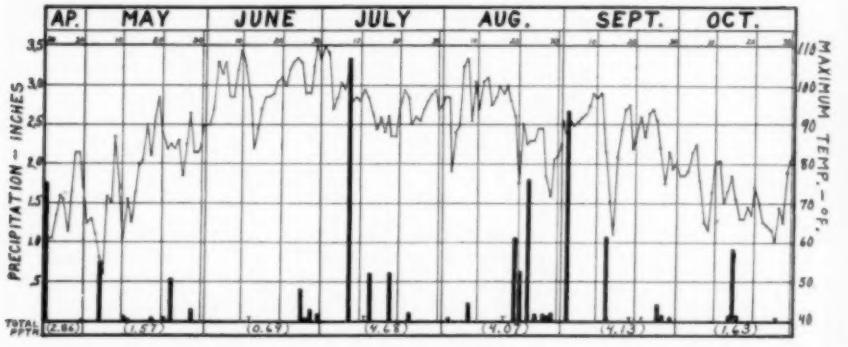

Fig. 3.—Precipitation and temperature at Manhattan, Kans., during summer of 1933.

The collection records for 1934 show the effects of the unprecedented heat and drought of this season on Chloropidae. In 1934, 15 days of June, 27 days of July and 19 days of August, totalling 61 days, had maximum temperatures of 100° F or higher. Of these, 23 days had maximum

temperatures of 110° F of higher. The total rainfall for June, July and August was 3.54 inches. During this period very few chloropids were collected. After June 22, only 13 *Madiza* and three other chloropids were taken until September 5. A comparison of fig. 1 with fig. 5 strikingly emphasizes the absence of the summer emergence.

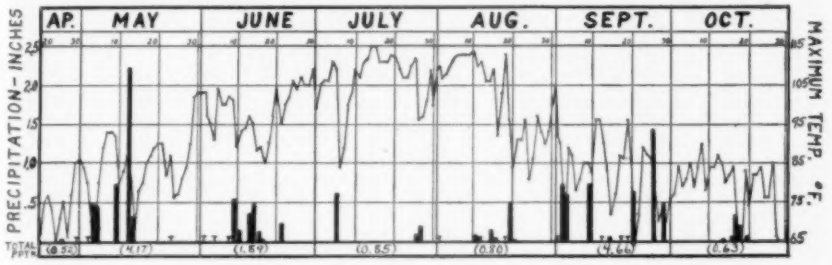

Fig. 4.—Precipitation and temperature at Manhattan, Kans., during summer of 1934.

Attention is called to the apparent relationship between the emergence of chloropids and the rainfalls exceeding one-half inch as shown in the 1933 collection records, fig. 1, and the rainfall chart, fig. 3. The first generation of adults in 1933 closely followed a generous rain of 1.77 inches on April 21, the second followed a downpour of 3.35 inches on

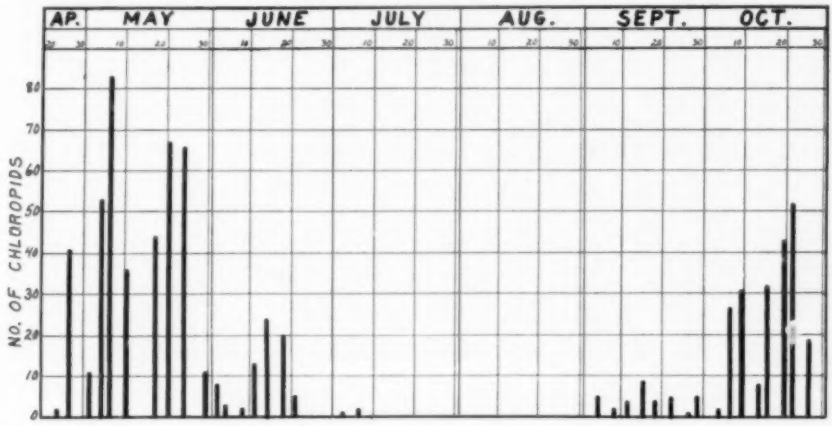

Fig. 5.—Collections of Chloropidae for 1934.

July 8, and the third came after the 1.06-inch rain of August 20 and the 1.81-inch rain of August 23. A similar relationship exists in collections of 1934, fig. 5, and the rainfall chart, fig. 4, with the exception of a few of the first generation of *Meromyza americana* which appeared slightly in advance of the rains.

In the extensive collections of 1930 from 31 plots of introduced grasses, there was little evidence of grass preference by adult chloropids. For ex-

ample, there were 18 plots from which 25 or more specimens of *Oscinella minor* and *O. frit* were taken. In 1933 and 1934, however, 123 of a total of 130 specimens of a *Madiza* sp. near *triangulata* were taken from collections on Kentucky blue grass. This species furnished the only suggestion

Fig. 6.—Injury to *Muhlenbergia racemosa* by *Anthracophaga ingrata*. **Fig. 7.**—Longitudinal section of culm of *M. racemosa* showing destruction of the upper portion of the culm with the swelling below caused by *A. ingrata*. The puparium remains in the position from which the fly emerged. The characteristic broomlike growth of the lateral branches is clearly evident.

of host preference in the collections. It is evident from table 1 that the introduced grasses were much better collecting areas for chloropids than were the native prairie grasses.

In addition to the preceding collection records, specimens of *Anthracophaga ingrata* (Will.) were reared from grasses of the genus *Muhlenbergia*. *Muhlenbergia racemosa* (Michx.) from near Manhattan, Kans.,

yielded the most specimens, but some also were bred from *Muhlenbergia* sp. from Marion county and *Muhlenbergia* sp. probably *Schreberi* Gmel. from Jackson county, Kans. The destruction of the upper part of the central culm was brought about by larval feeding similar to that of larvae of *Meromyza americana*. Below the dead section of the culm the internodes were shortened and swollen, forming a gall-like structure. Above each node of this gall a branch was given off, which, due to the shortened internodes gave the infested culm a bushy or broomlike appearance, figs. 6, 7. *Anthracophaga ingrata* was originally reared from gall-like swellings from *Muhlenbergia mexicana* by F. M. Webster in Ohio. A few other species of Chloropidae, including at least one member of the same genus[4] have been reared from galls on grasses.

Table 1.—Numbers of Chloropidae collected on different pastures.

Year	Kentucky Blue-grass Pasture	Brome and Orchard-grass Pasture	Native Prairie-grass Pasture
1933	3003	1205	201
1934	578	302	92
Total	3581	1507	293

[4] *Anthracophaga distichliae* Malloch was reared from a bract-covered gall on *Distichlis apicata* in California. Jour. Econ. Ent. 11: 386–7. 1918.

COLD STORAGE AS A CONTROL FOR GLADIOLUS THRIPS

R. H. Nelson, *U.S.D.A., Bureau of Entomology and Plant Quarantine*[1]

In Florida and parts of California, and probably in other areas having very mild winters the gladiolus thrips *Taeniothrips gladioli* M. & S. lives out of doors throughout the year. In the northern states and Canada however, the only known way in which it is able to pass the winter is on the stored corms. Obviously, therefore, the most desirable time for applying control measures in the north is during the storage season. A number of chemical treatments are now available which when properly used will control this thrips by eliminating infestations on stored corms.

In life history studies of this thrips by Floyd F. Smith, the results of which are incorporated in a paper by Weigel, Smith & Richardson (*5*) mention was made of the fact that "The failure of the eggs to hatch when incubated at 50° F may also have a practical use in the storing of corms at low temperatures as a possible factor in control." Reporting later on similar studies, Smith & Nelson (*3*) state that "none of the hundreds of eggs in cormels held for four or five weeks at 50° hatched at that temperature or when returned to room temperatures after such exposure . . . . In 13 laboratory tests to determine the effect of cold storage on the eggs it was found that larvae hatched from eggs in corms which were returned to room temperature after exposure of four days or less at 33° F, but that none hatched from corms which had been chilled for seven to 22 days."

[1] The author is indebted to C. A. Weigel, under whose general supervision this work was performed, and to Floyd F. Smith for suggestions and aid rendered during these studies.

These results suggested the possible utilization of cold storage as a control measure against the gladiolus thrips, and the work herein reported was undertaken to determine whether storage of infested corms at constant low temperatures would kill the thrips, If such effect could be obtained it would preclude the necessity for additional treatment and eliminate the necessity for much extra handling of the corms.

While the lethal effect of cold storage or refrigeration on various insects has been reported by numerous investigators, very little work of this nature has been done on the gladiolus thrips. A preliminary statement of the results obtained by the writer and discussed herein was made in a recent paper by Weigel (*4*). Pridham & Shaw (*2*) reported that corms

Table 1.—Results of cold-storage tests on *Taeniothrips gladioli* on gladiolus corms during the winter of 1932–33.

Temperature (F)	Length of Treatment, Months	No. Lots	No. Corms	No. Thrips Counted				Percentage Mortality Post-egg Stages	Living Thrips at Second Examination[3]
				Larvae	Pupae	Adults	Total		
30	½	1	30	116	6	2	124	100	Present
30	1	4	140	289	43	64	396	100	None
30	1	2	60	172	13	7	192	100	Present
30	2	6	180	446	28	162	636	100	None
36	1	3	60	270	105	75	450	98.9	
36	2	5	175	252	64	117	433	100	None
36	3	1	35	67	10	4	81	100	Present
40	1	1	30	41	2	10	53	81.1	
40	2	4	120	209	27	190	426	99.5	
40	3	5	185	240	106	65	411	100	None
50	1	1	30	34	27	11	72	26.4	
50	2	1	30	10	26	177	213	33.3	
50	3	1	30	11	2	69	82	82.9	
50	4	1	30	14	3	42	59	62.7	
50	5	1	30	8	2	54	64	65.6	

which were stored throughout the winter at 60° F became infested with thrips; that a change from 60° to 32° for as short a period as one month prevented further injury, and that corms stored initially at 32° F did not become infested. More recently Herr (*1*) has found that corms which had been heavily infested when placed in storage had no living thrips present when examined after being held three months at approximately 40° F.

Procedure and methods.—The corms used in these studies were divided into lots of from 15 to 100 each, placed in paper sacks and intentionally infested with thrips; then the tops of the bags were folded several times and fastened with paper clips. They were then left at room temperature for a sufficient time to insure the development and presence of all stages of the insect. However, they were placed in storage[2] while there was still sufficient corm surface which had not been fed over to eliminate starvation as a mortality factor. This also reduced excessive suberization as a cause of eggs failing to hatch if any were viable at the end of the treatment.

[2] Through the kindness of R. C. Wright, of the Bureau of Plant Industry, the tests were made in the cold-storage laboratory at Arlington Farm, Rosslyn, Va.

[3] The possibility of accidental reinfestation during the initial examination makes it doubtful that the living thrips found at this time were due to post-treatment hatching of eggs laid before or during the storage period.

Examination for mortality was made by removing the tunic from each corm and counting all the thrips on the corm and in the tunic under a wide-field binocular. The tunic was removed over a sheet of white paper, and this as well as the debris in the bag was also examined for thrips. The insects were recorded as to stage of development and whether living or dead.

In the tests of 1932–33 this examination was made a day or two after removal from storage. In those lots in which 100 per cent mortality of all post-embryonic stages occurred, the corms were replaced in the sack, the tops of the bags refastened, and the bags with their contents held at room temperature for a month or so. The contained corms were then re-examined to determine whether any later hatching had occurred. This method of examination gave accurate results on the mortality of all stages except the egg. It was of doubtful value, however, in checking on post-treatment hatching, for the following reason: accidental reinfesta-

Table 2.—Results of cold storage tests on *Taeniothrips gladioli* on gladiolus corms during the winter of 1933–34.

Temperature (F)	Length of Treatment, Months	No. Lots	No. Corms	No. Thrips Counted				Percentage Mortality Post-egg Stages
				Larvae	Pupae	Adults	Total	
36	2	9	350	369	110	93	572	100
36	3	6	250	260	52	52	364	100
40	3	6	250	271	62	50	383	100
40	4	4	150	138	31	36	205	100

tion was possible at the time of the first examination because thrips were present on gladiolus plants in a greenhouse adjoining the laboratory, and additional hatchings might have been either from eggs that had survived the treatment or from some introduced since.

In the tests of 1933–34, in which only temperatures shown by the earlier tests to be lethal to post-egg stages were used, the first examination was omitted. That is, the corms after removal from cold storage were left in the unopened sacks at room temperatures for a month or so and then examined. This was more than ample time for any viable eggs to have hatched. Any living thrips found by this method would have been due to later hatching.

Results.—The results of the tests of 1932–33, which are summarized in table 1, indicate that exposure of infested corms at 30° F for one-half, one and two months, at 36° for two months and at 40° for three months, produces a complete kill of all post-embryonic stages of the thrips. There was survival at 36° for one month, at 40° for one and two months, and at 50° for all exposures tried—one month to five months, inclusive.

At the second examination living thrips were found in the lot held at 30° F for one-half month, in two lots held at 30° for one month, and in one lot held at 36° for two months. These, however, were believed to have come from accidental reinfestation at the time of the initial examination and not to post-treatment hatching.

Since about half of the corms of one variety held at 30° F were ruined by freezing, this temperature was eliminated from further tests.

The results of the tests at 50° F show that after one month 84.7 per

cent of the thrips present were in the pre-adult stages, while 15.3 per cent were adults. These percentages were practically reversed in the remaining lots held from two to five months. These figures indicate that no hatching had occurred on these corms but that there had been a slow development of the immature forms that were present when the corms were placed in storage. This is in agreement with the findings of Smith & Nelson (*3*).

In the results of the tests of 1933–34, which are summarized in table 2, it will be noted that complete mortality resulted when infested corms were subjected to a temperature of 36° F for two and three months, respectively, and to 40° for three and four months, respectively. Since no living thrips were found in any of the 25 lots when examined, after the corms had been held at room temperatures for one month, it seems justifiable to conclude that the temperatures and exposures indicated are lethal to all stages of the gladiolus thrips.

Table 3.—Surviving stages of *Taeniothrips gladioli* at the various storage temperatures, tests of 1931–33.

Temperature (F)	Length of treatment Months	No. Dead				No. Surviving			
		Larvae	Pupae	Adults	Total	Larvae	Pupae	Adults	Total
36	1	270	100	75	445		5		5
40	1	33	2	8	43	8		2	10
40	2	207	27	190	424	2			2
50	1	12	1	6	19	22	26	5	53
50	2	3	4	64	71	7	22	113	142
50	3	9		59	68	2	2	10	14
50	4	13	2	22	37	1	1	20	22
50	5	6	1	35	42	2	1	19	22

Resistant stages.—The date on survival of the thrips at the various temperatures summarized in table 3 are too limited for definite conclusion. However, it appears that the larvae, pupae and adults are of about equal resistance, and, on the basis of the results of Smith & Nelson (*3*) it is evident that the eggs are much less resistant to cold than are the post-embryonic forms.

Discussion.—The tests herein reported were run on lots of 100 corms or less in paper sacks. It has been suggested that under certain commercial conditions where the corms are stored in large containers these results might not apply. Under such conditions the heat of respiration of the corms would keep the temperature within the container above that of room temperature. Whether or not the difference would be sufficient to affect the mortality of the thrips remains to be determined.

Where the corms are stored in shallow trays placed in racks, permitting free air circulation, as is done in most commercial storage houses, they would cool as readily as they do in paper sacks, and the use of cold storage as a control for the thrips would seem to be feasible for those growers who have access to storage plants where constant temperatures between 35 and 40° F can be maintained. Winter storage of the corms is a regular practice in the culture of gladiolus; and it would seem that if the storage conditions can be so arranged as to be lethal to any thrips present, it would save considerable time, extra handling and expense.

Under any circumstances, the value of storing the corms in as cool a

location as possible above freezing is self-evident and of interest to all gladiolus growers. Such storage retards development and activity of the thrips, hence reduces corm injury; and chemical treatments, such as with naphthalene flakes, may be applied during the winter at the grower's convenience.

Summary.—The results of two seasons' experiments show that all stages of the gladiolus thrips can be completely eliminated by storing the infested corms at a constant temperature of 36° F for two months, or 40° F for three months.

Limited data indicate that the larvae, pupae and adults are of about equal resistance to cold. On the basis of earlier work the eggs are much less resistant than the later stages. This method of thrips control in storage shows promise of being commercially practical.

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LABORATORY METHOD OF COMPARING THE TOXICITY OF SUBSTANCES TO SAN JOSE SCALE[1]

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One of the chief problems of the insect toxicologist is the heterogeneity of insect populations. Because of significant differences in viability of populations, erroneous conclusions are frequently drawn. To overcome this variability as much as possible insects used in insecticide studies are reared in the laboratory under uniform conditions. There are, however, relatively few experimental insects that can be reared easily under uniform conditions and that are sufficiently homogeneous at all times. As a result the insect toxicologist is frequently compelled to work with heterogeneous populations.

Preliminary experiments with the San Jose scale, *Aspidiotus perniciosus* Comstock, revealed that the population obtained from the field was very heterogeneous in regard to viability. In order to obtain homogeneous results it was necessary to devise a method that would be adequate in technique and experimental design. The following method has given very good results.

[1] Early publication of this paper has been secured by payment of the printing charge.

Experimental design.—Branches about one-half inch in diameter and well infested with San Jose scales were cut from apple trees in the vicinity of Ames, Iowa. The trees from which the branches were pruned had never been sprayed for this insect and as a result parts of the trees were very heavily encrusted. Branches that were heavily encrusted were avoided in collecting the material because on such branches the scale could not be treated uniformly. The smaller branches were pruned and the main branches were cut in lengths from 12 to 16 inches. It was assumed that the scale population on each length was homogeneous, *i.e.*, samples drawn from the population would not differ significantly in viability. It is imperative that substances whose toxicities are to be compared be tested on a homogeneous scale population; therefore, each of the lengths were subdivided in groups of five or six pieces depending on the number of different materials to be tested. One stick from each group was set aside for the control and the remaining sticks were sprayed with the emulsions containing varying percentages of dinitro-o-cyclohexylphenol dissolved in the oil phase. The pieces were chosen at random from the groups and were maintained in a definite order with respect to the groups and the treatment received.

Procedure.—Each piece was impaled on the end of a dissecting needle, inserted through a hole at the base of the bell jar of an apparatus similar to that described by Tattersfield & Morris (*2*), and sprayed with 2.5 cc. of a specified diluted emulsion at a pressure of 10 pounds per square inch. The needle was revolved continuously during the spraying procedure in order to insure complete coverage of the scale. The stick was then removed from the needle and set aside with the corresponding control of the group. After treatment the groups were placed at constant temperature (30° C) and humidity (about 70 per cent) for a period of 72 hours. At the end of this time the mortality determinations were made. Preliminary tests showed that 72 hours was sufficient time; when the time was increased beyond 72 hours the mortality of the control scales increased rapidly. It was therefore very important that the scales be checked at the end of the 72-hour period.

The covers were carefully lifted from 60 overwintering scales that were examined at random from all parts of each of the sticks or branch sections of the groups. Failure of the scale to respond when probed with a dissecting needle, a marked shrivelling, and an orange-brown color, the latter contrasting with the lemon yellow color of the normal live scale, were employed as criteria of death.

Statistical analysis.—In order to test the homogeneity of the scale population, the adequacy of the technique and the reliability of the experimental design, the chi-square (χ^2) test for homogeneity was applied. Results obtained by the method that has been outlined were tested for homogeneity with the method of computation outlined by Snedecor & Irwin (*1*). The values of chi-square in the controls from group to group, *i.e.*, among the subsamples, showed that the probabilities of death for the untreated scale differed significantly from branch to branch. This means that the differences in the normal percentage mortalities were greater than could be attributed to random sampling from a homogene-

ous population. It was very reasonable to expect that the normal mortality of San Jose scales in the field would be quite different from branch to branch and tree to tree. In view of this heterogeneity it should be expected that the percentage mortalities obtained with different treatments would vary significantly from group to group. This is precisely what happened. For example, in table 1 under treatment A[2] the value of chi-square is 64.922 for the percentage mortalities among the 17 subsamples. It is noted upon entering a table of chi-square with $17-1=16$ degrees of freedom that the probability of occurence of such a value of chi-square in random sampling is less than .01. Therefore, these subsample mortalities are heterogeneous.

Table 1.—Results obtained with three emulsions of dinitro-o-cyclohexylphenol dissolved in petroleum oil and applied to San Jose scale.

	Treatment A (Petroleum Oil)			Treatment B (Petroleum Oil +.1 per cent DNOCHP)[4]			Treatment C (Petroleum Oil +.5 per cent DNOCHP)			Total	
Group No.	Actual No. Dead[3]	Expected No. Dead	Chi-square (χ^2)	Actual No. Dead	Expected No. Dead	Chi-square (χ^2)	Actual No. Dead	Expected No. Dead	Chi-square (χ^2)	No. Dead	Chi-square (χ^2)
1	32	30.630	.0612	47	45.589	.0437	51	53.781	.144	130	.249
2	39	34.635	.5501	51	51.551	.059	57	60.814	.239	147	.848
3	38	33.929	.4884	51	50.498	.005	55	59.573	.351	144	.844
4	21	26.860	1.278	45	39.978	.631	48	47.162	.015	114	1.924
5	28	33.457	.890	57	49.797	1.042	57	58.745	.052	142	1.984
6	47	38.877	1.697	58	57.863	.0003	60	68.260	.999	165	2.696
7	17	23.326	1.716	38	34.718	.310	44	40.956	.226	99	2.252
8	28	29.688	.096	40	44.186	.396	58	52.126	.661	126	1.153
9	24	29.688	1.089	43	44.186	.318	59	52.126	.906	126	2.313
10	26	30.159	.573	47	44.888	.099	55	52.953	.079	128	.751
11	25	27.331	.199	41	40.679	.0025	50	47.989	.084	116	.286
12	30	29.688	.0034	40	44.186	.396	56	52.126	.287	126	.686
13	28	26.860	.048	38	39.978	.908	48	47.162	.015	114	.161
14	33	30.866	.148	47	45.940	.024	51	54.194	.188	131	.360
15	33	28.981	.576	39	43.134	.396	51	50.885	.0003	123	.972
16	37	32.986	.488	49	49.096	.0002	54	57.918	.265	140	.753
17	30	28.038	.137	37	41.731	.536	52	49.230	.156	119	.829
Total	*516*	*516*	*10.037*	*768*	*768*	*4.357*	*706*	*906*	*4.6673*	*2190*	*19.061*

The following questions present themselves. Is the lack of homogeneity among the subsamples under various treatments due entirely to the heterogeneity of the scale population, or is it because of the treatment applied? If the only disturbance in the results were due to a difference in viability of the 17 groups of scale, the mortalities due to the treatments should always appear in the same proportion. Do these values depart significantly from proportionality?

To facilitate explanation, a portion of some original scalicidal data, together with the statistical results, have been prepared in table 1. The table has been arranged in 17 groups of three treatments and corresponds precisely to the experimental design that has been given. The data under the columns designated "Actual Number Dead" were taken from the original data and each value is the number of dead scale recorded from the subsample of 60. The values under the columns designated "Expected Number Dead" were calculated by proportion from the observed

[2] The toxicity of solutions of dinitro-o-cyclohexylphenol in petroleum oil has been taken up in detail in another publication, Jour. Econ. Ent. 29(1): 52. Feb. 1936. It will suffice as far as explanation of the method is concerned to refer to the different treatments as lettered.

[3] Number of dead scale recorded from a subsample of 60 scales. The total number of scales counted with each treatment was 1020.

[4] DNOCHP = dinitro-o-cyclohexylphenol.

totals. For example, under treatment A, group 8, the expected number of dead scale is calculated:

$$\text{Expected number dead} = \frac{(126)(516)}{2190} = 29.688$$

These expected values have been arranged opposite their respective actual values. The columns for the actual and expected number of dead scales must agree in their sums. The same calculations were then made with the numbers of scale living. Uusually, the two estimated numbers, dead and alive, did not add to 60, necessitating an adjustment to correct the subsample total. The value for chi-square was then calculated by the formula

$$\chi^2 = S\frac{(x-m)^2}{m}$$

in which x is the actual number of dead or alive scale in each subsample and m is the expected number. The value of chi-square[5] for the entire table is the summation of the contributions made by each subsample, the result being 53.4. Upon entering a table of chi-square with $1 \times 2 \times 16 = 32$ degrees of freedom, the value of chi-square shows that the probability (P) is greater than .01, indicating a significant but not serious departure from homogeneity. It is believed that this approximation to the exact valued chi-square is too large. If so, the actual numbers and the expected

Table 2.—A statistical comparison of three average percentage mortalities obtained with three emulsions applied to San Jose scale.

Treatments	Number of Scales	Number Dead	Average Percentage Mortality	Chi-square (χ^2)
A	1020	516	50.58823	
B	1020	768	75.29411	
C	1020	906	88.82352	
Totals	3060	2190	Mean = 71.56862	$\chi^2 = 376.855$ (P = < .01)

numbers do not differ seriously. If there were a great differential viability of the scale within groups or if the experimental technique were inadequate, the departures of the actual values from proportionality should have been more pronounced. Therefore, within the limits of sampling variation, the scale within each group may be regarded as fairly homogeneous and the technique of handling it adequate. The lack of homogeneity among the subsamples under various treatments was not because of the treatment applied but due entirely to the heterogeneity of the scale population between branches. This heterogeneity between the groups of scale has not affected the homogeneity of the results because each treatment was applied to the same homogeneous scale population within each group.

Average (weighted mean) percentage mortalities that were obtained with the three treatments were calculated from the totals of table 1. These values were tested for significant differences by means of the chi-

[5] The chi-square test employed in this analysis is an approximation to the second order interaction in this $2 \times 3 \times 17$ table. No exact method has been devised. One can be reasonably sure that the correct value is less than that given.

square test for homogeneity. The data for the average percentage mortalities together with the statistical results have been summarized in table 2. The value of chi-square for the three percentage mortalities is 376.855 and was computed by the method of Snedecor & Irwin (*1*). It is noted, upon entering a table of chi-square with $3-1=2$ degrees of freedom, that the value for chi-square is far outside the range of the table, which shows highly significant differences in the three percentage mortalities.

The experimental method that has been designed for comparing the toxicity of various substances to the San Jose scale affords a means by which homogeneous results can be obtained and accurate comparisons of materials made without danger of erroneous conclusions being formulated. The method further demonstrates that conclusive results can be obtained with a heterogeneous insect population provided that homogeneous groups, each of sufficient size to provide for the desired treatments, can be drawn from the population.

The author believes that the method can be extended for usage in toxicity studies with other scale insects. The general design can be employed for comparing the toxicity of substances, particularly in cases where the viability of the insect population is significantly variable. The statistical methods that have been employed are very useful for testing the adequacy of the experimental technique, the homogeneity of the populations, and for ascertaining whether the departures of the results from expectancy are of a magnitude ascribable to the chances of random sampling.

The writer wishes to take this opportunity to thank Professor G. W. Snedecor, Department of Mathematics, Iowa State College, for advice on statistical matters.

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TOXICITY OF SOME NITRO-PHENOLS AS STOMACH POISONS FOR SEVERAL SPECIES OF INSECTS[1]

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Synthetic organic compounds appear to offer excellent possibilities for the development of efficient stomach poisons for insects. However, only a few compounds whose toxicities to certain insects have been evaluated on an individual dosage basis have compared favorably in toxicity with the arsenicals. This paper includes the results obtained with a group of nitro-phenols of which 2–4 dinitro-6-cyclohexylphenol and some of its

[1] Early publication of this paper has been secured by payment of the printing charge.

salts have shown considerable promise as stomach poisons for insects.

Materials and methods.—The insects employed in these experiments were the corn ear-worm *Heliothis obsoleta* Fabricius, the army worm *Cirphis unipuncta* Haworth, the imported cabbage worm *Ascia rapae* L. and the red-legged grasshopper *Melanoplus femur-rubrum* DeGeer.

The organic chemicals[2] used in the stomach poison experiments were as follows: 2–4 dinitro-6-cyclohexylphenol[3] and its calcium, magnesium, copper and lead salts; calcium 2–6 dinitro-4-cyclohexylphenate; calcium 2–4 dinitro-6-phenylphenate; lead 3–5 dinitro-o-cresylate (lead 2–4 dinitro-6-methylphenate). The sample of acid lead arsenate ($PbHAsO_4$), PbO 64.5 per cent, As_2O_5 .22 per cent, was obtained from Richardson & Thurber (*10*). The sample of arsenic trioxide, As_2O_3, was chemically pure.

Campbell & Filmer (*5*) published a quantitative method for the administration of known dosages of toxic compounds to the silkworm. By means of this method it is possible to determine median lethal dosages of stomach poisons. Following this paper Campbell (*3*), Stellwaag (*12*), Richardson & Haas (*9*), and Bulger (*1*, *2*), have suggested many improvements and modifications. A modified method[4] for feeding lepidopterous larvae and calculation of individual dosages was employed in these experiments. The method published by Richardson & Haas (*9*) and Richardson & Thurber (*10*) for the administration of known dosages of toxic compounds in baits to adult grasshoppers was followed in detail.

Each day's lot of treated insects was accompanied by controls or check insects obtained from the same population. There was very little parasitism among the controls and among the treated insects. Furthermore, very few cases of wilt disease were observed. With the grasshoppers and the three species of lepidopterous larvae the mortality in the controls was small enough to be considered negligible and was therefore disregarded in calculating the results.

Results.—The results with acid lead arsenate and the several organic compounds in toxicity experiments with the corn ear-worm, army worm, cabbage worm and grasshopper have been summarized in table 1. The data were arrayed according to dosages and grouped into the three zones, the lethal, sublethal and intermediate. The latter zone, which is of primary interest, is delimited by those dosages that were lethal to some and sublethal to others. The data were not grouped into time survival groups according to the method of Richardson & Haas (*9*) because the writer was primarily interested in the ultimate death or recovery of the insects. The survival times were determined approximately and have been summarized in the table.

A comparison of the means by the small sample method of Fisher (*6*) showed that 2–4 dinitro-6-cyclohexylphenol and the calcium, mag-

[2] The organic chemicals were prepared by the research laboratories of the Dow Chemical Company, Midland, Mich.

[3] U. S. Patent No. 1,880,404.

[4] In this investigation the modified method of feeding the larvae and calculation of the known dosages was worked out by Richardson & Hansberry (unpublished method). They combined some of the ideas given previously by the other workers and offered a few changes in the technique. Since the changes made in the leaf-sandwich method of Campbell & Filmer (*5*) will be given in detail in a later publication it is considered unnecessary to summarize the technique in this paper.

Table 1.—Toxicity of some nitro-phenols as stomach poisons for several species of insects.

Compound	Median Lethal Dosage *mg. per gram of insect body weight*	Lethal Zone			Sublethal Zone		Intermediate Zone						
							Dead				Recovered		
		No. Insects	Mean Survival Time *hours*	Dosage Range	No. Insects	Dosage Range	No. Insects	Mean Survival Time *hours*	Dosage *mg. per gram of insect body weight* Range	Mean	No. Insects	Dosage *mg. per gram of insect body weight* Range	Mean
Corn Ear-worm													
Acid lead arsenate	.26	11	14	.36 –.66	45	.04 –.18	15	23	.18 –.33	.27	14	.19– .33	.25
2–4 dinitro-6-cyclohexyl-phenol	.087	6	3	.149–.2	26	.009–.057	22	4	.06– .125	.091	25	.06 –.146	.082
Calcium salt	.059	20	3	.109–.221	27	.013–.027	24	5	.029–.105	.06	27	.029–.107	.058
Magnesium salt	.077	5	2	.136–.188	14	.008– .04	21	4	.041–.133	.082	17	.044–.134	.073
Lead salt	.084	10	3	.141–.232	10	.004–.053	14	3	.054–.128	.088	16	.054–.137	.08
Copper salt	.097	5	3	.157–.194	23	.011–.049	19	4	.051–.138	.098	14	.053–.143	.096
Calcium 2–4-dinitro-6-phenylphenate	<.246–>.034	1	10	.246–.246	16	.011–.033	6	8	.034–.079	.06	36	.034–.139	.069
Calcium 2–6-dinitro-4-cyclohexylphenate	>.5				94	.003–.5							
Lead 3–5-dinitro-o-cresylate	>.13				41	.01 –.13							
Army Worm													
Acid lead arsenate	.26		15					20					
Calcium 2–4-dinitro-6-cyclohexylphenol	.015	26	4	.022–.237	12	.001–.008	22	9	.009–.021	.016	21	.009–.021	.015
Imported Cabbage Worm													
Acid lead arsenate	.09		17					24					
Calcium 2–4-dinitro-6-cyclohexylphenol	.073	22	3	.106–.336	12	.01 –.036	17	6	.042–.099	.075	19	.043–.104	.071
Red-legged Grasshopper													
Arsenic trioxide	.137	52	22	.206–1.32	16	.034–.064	23	43	.064–.195	.139	29	.072–.202	.134
2–4-dinitro-6-cyclohexyl-phenol	.056	49	14	.095–.913	19	.01 –.034	13	20	.035–.077	.056	12	.036–.087	.055
Calcium salt	>.5				13	.076–.5	4	17	.527–.81	.664	3	.523–.93	.694

nesium, lead and copper salts were very significantly more toxic to the corn ear-worm than acid lead arsenate. The calcium salt with a median lethal dosage of about .059 mg. per gram was the most toxic of the lethal compounds and was more than four times as toxic as acid lead arsenate, which had an M.L.D. of about .26 mg. per gram. The copper salt of 2–4 dinitro-6-cyclohexylphenol was the least toxic of the lethal organic compounds yet it was nearly three times as toxic as acid lead arsenate.

A statistical treatment of the data in the intermediate zones for dosages of 2–4 dinitro-6-cyclohexylphenol and its salts was made according to the method of expected numbers for tables of multiple classification with disproportionate subclass numbers (*11b*). The analysis of variance (*11a*) is given in table 2.

Variation from known sources between the larvae that died and those that recovered in the intermediate zone, between the means of treatment with dinitro-o-cyclohexylphenol and its salts, and the interaction, have been segregated from the total mean square. The remainder, the variation within the classes, is properly attributed to experimental error.

Table 2.—Analysis of variance of the dosages of 2-4 dinitro-6-cyclohexylphenol and four of its salts.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	198	.153658	.000776
Within classes	189	.116673	.000617
Between means of dead and recovered	1	.001888	.001888
Between means of treatments	4	.034683	.008671
Interaction	4	.000414	.000104

The mean square between the larvae that died and those that recovered in the intermediate zone is not significantly different from the experimental error as evidenced by the statistic, $F = .001888/.000617 = 3.0599$. Therefore, the two means for each of the compounds differ only so much as would be expected in random sampling from a homogeneous population. Furthermore, it was expected that in the intermediate zone a similar mean dosage which was not significantly different would be obtained with the larvae that recovered as compared with the larvae that died. This is evidenced by the nonsignificance of the interaction, which is a measure of the failure of the differences of the means to be alike. The analysis thus far shows rather conclusively that the mathematical average of the mean dosage of larvae that died and the mean dosage of larvae that recovered is a good criterion of the M.L.D., which is a mathematical estimate of the dosage required to kill 50 per cent of the population.

The mean square between means of treatments with 2–4 dinitro-6-cyclohexylphenol and its salts is highly significantly different from the experimental error ($F = .008671/.000617 = 14.053$), thus showing that the M.L.Ds. of the five compounds are heterogeneous and that the chances are less than one in a hundred of obtaining similar values in random sampling from a homogeneous population. The median lethal dosages were compared, using the variance .000617 with its associated standard deviation of .0248 mg. per gram as the standard against which to test

significance. The calcium salt was the most toxic, the copper salt was the least toxic, while the magnesium and lead salts, the M.L.Ds. of which were not significantly different, occupied an intermediate position. The M.L.Ds. of the magnesium, lead and copper salts were not significantly different from the M.L.D. of the parent phenol, 2–4 dintro-6-cyclohexylphenol. The calcium salt, however, was very significantly more toxic than the phenol.

It is difficult to propose a reasonable explanation for the differences in toxicity displayed by 2–4 dinitro-6-cyclohexylphenol and the four salts to the corn ear-worm. There are a multitude of rather intangible factors that might be responsible, such as solubility differences of the compounds in the intestine of the insect, synergistic and antagonistic actions of the anions and cations, permeability, possible differences of reactions and rates of reactions with digestive secretions, and other physical, physiological and chemical differences in their behavior. A comparison of the toxicities of the salts with the parent phenol shows that in the case of the lead and copper salts the metallic ions probably add sufficiently to the toxicity to compensate for a loss of toxicity due to the percentage decrease of 2–4 dinitro-6-cyclohexylphenol contained in the molecules of their salts. Since the elements, calcium and magnesium, are not known to possess outstanding toxic properties, no suitable explanation other than solubility relationships justifies the relative toxicities obtained with their respective salts. Although the differences between the M.L.Ds. of the salts, with the exception of those given, are very highly significant statistically, the toxicities of the phenol and the four salts are of the same general order with mean differences that are not numerically large. The compounds possess approximately the same mean survival times and produced as well as could be observed about the same toxic symptoms.

Calcium 2–4 dinitro-6-phenylphenate, calcium 2–6 dinitro-4-cyclohexylphenate and lead 3–5 dinitro-o-cresylate were not sufficiently toxic as stomach poisons to estimate M.L.Ds., but the data were considered sufficiently interesting to be summarized in table 1. Calcium 2–4 dinitro-6-phenylphenate showed definite toxicity as a stomach poison to the corn ear-worm, but was too distasteful in large dosages to estimate the M.L.D. Calcium 2–6 dinitro-4-cyclohexylphenate failed to kill a single larva with dosages as high as .5 mg. per gram. The fact that this compound had little toxicity as a stomach poison was considered rather interesting because it differs structurally from the very toxic calcium 2–4 dinitro-6-cyclohexylphenate only in the reversal of groups in the ortho and para positions. Jackson & LeFroy (*8*) and Hargreaves (*7*) concluded that the ammonium and potassium salts of 3–5 dinitro-o-cresol were the most toxic as stomach poisons for house flies and certain lepidopterous larvae. These workers observed that the salts were very deterrent. It is rather interesting to note, in regard to the present investigation, that the lead salt of 3–5 dinitro-o-cresol was found to be very distasteful and nontoxic to corn ear-worm larvae within the range of dosages consumed. Since the sublethal dosages taken by the larvae were within the lethal and intermediate zones for calcium 2–4 dinitro-6-cyclohexylphenate it may be concluded that the cresylate has a much lower order of toxicity.

The results of the toxicity experiments with the army worm have been arrayed and summarized in table 1. The M.L.Ds. of acid lead arsenate[5] and calcium 2–4 dinitro-6-cyclohexylphenate were determined to be about .26 and .015 mg. per gram respectively. These values show that the calcium salt is about 17 times more toxic than acid lead arsenate. A comparison of the mean survival times for the two compounds shows that the calcium salt has a much greater speed of toxic action.

The toxicity data given in table 1 on the cabbage worm show analogous results to those obtained with the corn ear-worm and the army worm. A statistical treatment of the data for the two compounds shows that calcium 2–4 dinitro-6-cyclohexylphenate (M.L.D. .073) is very significantly more toxic than acid lead arsenate (M.L.D. .095). The cabbage worm was less resistant to the acid lead arsenate and more resistant to the calcium salt.

In the stomach-poison experiments with the red-legged grasshopper the toxicities of 2–4 dinitro-6-cyclohexylphenol and its calcium salt were compared with arsenic trioxide, As_2O_3, which is commonly employed in grasshopper baits. Acid lead arsenate was not employed in experiments as a basis for comparison because the compound has rather limited toxicity (*9*) to grasshoppers and is not used in the baits. A comparison of the M.L.Ds. of the compounds as given in table 1 shows that 2–4 dinitro-6-cyclohexylophenol is more than twice as toxic as arsenic trioxide while the calcium salt of the phenol, which has consistently shown high toxicity to the insect larvae, had relatively low toxicity. Comparison of the survival time data shows that the speed of toxic action of the phenol is approximately twice that of arsenic trioxide. Bait mixtures containing large amounts of the calcium salt were so distasteful to the grasshoppers that efforts to feed lethal doses were futile. The data were inadequate for the estimation of the M.L.D.

Discussion of results.—Campbell's stomach-poison experiments with coal-tar dyes (*4*) showed that four lethal dyes had toxicities of the same order of magnitude as certain arsenicals. Malachite green (M.L.D. about .025 mg. per gram) was the most toxic dye tested and it was only 3.6 times more toxic than acid lead arsenate (M.L.D. about .09 mg. per gram) to the fourth-instar silkworm. In this investigation calcium 2–4 dinitro-6-cyclohexylphenate was found to be the most toxic stomach poison. The compound was consistently more toxic than acid lead arsenate to the corn ear-worm, army worm, and cabbage worm. The calcium salt was not very toxic to the red-legged grasshopper, but the phenol was about 2.5 times more toxic than arsenic trioxide.

The results of the army worm experiments indicate that calcium 2–4 dinitro-6-cyclohexylphenate is the most toxic synthetic organic stomach poison reported in the literature, since the M.L.D. of about .015 mg. per gram is smaller than those recorded for malachite green (*4*) and cuprous cyanide (*10*). A comparison of survival times show that the speed of toxic action of 2–4 dinitro-6-cyclohexylphenol and the four salts is about

[5] The M.L.Ds. of acid lead arsenate to the army worm and imported cabbage worm were determined by Richardson & Hansberry (unpublished data). The values were determined at the same time, by means of the same method, and with insects drawn from the same populations.

the same as malachite green and brilliant green although the survival time data for the dyes were determined by injection administration, rather than by mouth. The speed of toxic action for the dyes would very probably be much slower by oral administration.

Another point of interest is the fact that 2–4 dinitro-6-cyclohexylphenol is a dye from the standpoint that the molecule is in possession of chromophoric and auxochromic groups. The compound lacks, however, many essential characters necessary for good dye stuffs and is not termed a coal-tar dye. Furthermore, the phenol is only remotely related structurally to the triphenylmethane and safranine dyes found toxic by Campbell, and consequently it is unreasonable to assume a similarity of toxic action although they have apparently about the same relative toxicity, when the various species of insects used are disregarded.

The 2–4 dinitro-6-cyclohexylphenol has several advantages as a stomach poison over such a compound as malachite green. The phenol is practically insoluble in water whereas malachite green is easily soluble. The sodium salt of the phenol is water soluble, but the calcium, magnesium, lead and copper salts are only slightly soluble. It is probable that the compound has a further advantage in not being very toxic to man and several other vertebrates on which the chemical has been tested. Tainter *et al.* (*13*) found that 2–4 dinitro-6-cyclohexylphenol was 15 per cent less toxic than 2–4 dinitro-phenol to pigeons, and that a dosage of 20 mg. per kilogram, which is a rather large dosage, was fatal to dogs. Furthermore, the compound failed to stimulate metabolism in the rat and in man. The writer has worked with the chemical for three years without any noticeable injurious effects, such as skin rashes and other toxic symptoms characteristic of poisoning with certain nitro-phenols.

It has been previously pointed out that 2–4 dinitro-6-cyclohexylphenol and the four salts were several times more toxic than acid lead arsenate to the corn ear-worm. Other related organic chemicals, calcium 2–4 dinitro-6-phenylphenate, calcium 2–6 dinitro-4-cyclohexylphenate, and lead 3–5 dinitro-o-cresylate, that were tested as stomach poisons against the corn ear-worm, had little or no toxicity. The results with these compounds are interesting from the standpoint that they point out certain relationships of molecular structure to toxicity. Substitution of a phenyl or methyl group for the cyclohexyl group on No. 6 carbon atom of 2–4 dinitro-6-cyclohexylphenol greatly reduced or destroyed the toxicity of the molecule. Reversal of the groups in the 4–6 positions destroyed the high toxicity of the molecule. The cyclohexyl group in the ortho position to the hydroxyl group with nitro groups in the 2–4 positions is probably the most toxic arrangement. The intramolecular relationships of the several groups on the benzene ring are responsible for the toxicity, rather than any specific group. It is very probable that any change or deviation from the structure of 2–4 dinitro-6-cyclohexylphenol will greatly reduce toxicity. The data at present available concerning related and isomeric compounds are too inadequate for definite conclusions to be drawn.

Acknowledgments.—This paper constitutes a part of the insecticide research program of the Dow Chemical Company, Midland, Mich., which is being conducted as a fellowship under the supervision of the

Crop Protection Institute at Iowa State College, Ames, Iowa. The author wishes to express his thanks to the above organizations; to Dr. C. H. Richardson, Department of Zoology and Entomology, Iowa State College, for advice and criticism during the progress of this research; and to Mr. Lindley E. Mills, of the Dow Chemical Company, who has followed the investigations closely.

Summary.—Several organic compounds not previously examined for insecticidal value as stomach poisons have been administered by the leaf sandwich method to last-instar corn ear-worms, army worms, and cabbage worms. Two–4 dinitro-6-cyclohexylphenol and the calcium, magnesium, lead and copper salts were found to be several times more toxic than acid lead arsenate to the corn ear-worm. Calcium 2–4 dinitro-6-cyclohexylphenate, which was the most toxic salt examined, was about 4.4 times more toxic than acid lead arsenate to the corn ear-worm, 17 times more toxic than acid arsenate to the army worm and significantly more toxic than acid lead arsenate to the cabbage worm.

The speed of toxic action for 2–4 dinitro-6-cyclohexylphenol and the four salts was several times greater than for acid lead arsenate. The mean survival times ranged from two to five hours.

Arsenic trioxide, 2–4 dinitro-6-cyclohexylphenol and the calcium salt were fed quantitatively in baits to the red-legged grasshopper. The calcium salt displayed rather low toxicity but the phenol was 2.5 times more toxic than arsenic trioxide. Furthermore, the speed of toxic action was approximately twice that of the arsenical.

The chemicals related structurally to 2–4 dinitro-6-cyclohexylphenol had little toxity as stomach poisons. The indications were that deviations from the structure of the lethal phenol resulted in partial or complete loss of the high toxicity to insects.

The consistent and promising results obtained with 2–4 dinitro-6-cyclohexylphenol and the four salts appear to recommend them for practical consideration as stomach poisons for mandibulate insects.

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OBSERVATIONS ON *ANASTREPHA PALLENS* (COQ.)

REARED FROM WILD FRUITS IN THE LOWER RIO GRANDE VALLEY OF TEXAS DURING THE SPRING OF 1932

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The economic status of *Anastrepha* (*Pseudodacus*) *pallens* (Coq.) became a matter of concern when in the spring of 1931 inspectors of the Plant Quarentine and Control Administration discovered adults in citrus trees in the lower Rio Grande valley of Texas. A number of members of the genus *Anastrepha* are serious pests of cultivated fruits. Some better known relatives are the Mexican fruit fly *A. ludens* (Loew), the Central American fruit fly *A. striata* (Schin.), the West Indian fruit fly *A. acidusa* (Walk.)—formerly considered a synonym of *A. fraterculus* (Wied.)—and the dark fruit fly *A. serpentina* (Wied.). The species *pallens*, which is little known, resembles *A. ludens* in general appearance, differences in color markings and the fact that *pallens* is considerably the smaller having served as means of separating the two species. These characters, however, are subject to considerable variation. Much more reliable differences are to be found in the ovipositors and male claspers.

The type specimen was taken at Brownsville, Tex., in 1904,[1] when citrus was hardly known in that district; but when adults were found in citrus trees in 1931 there seemed to be the possibility that the species was breeding in grapefruit or oranges and that its larvae might not be distinguishable from those of *A. ludens*. As a consequence the writers undertook an investigation of the species in the spring of 1932, the results of which are given in this paper.

Procedure.—When the authors started work on the problem, adult flies had already been captured in citrus trees at several points throughout the citrus area of the valley. These places were visited and a careful study of the surroundings of each point was made. Vegetables, citrus and all other possible host material then available, including bananas, dates

[1] Coquillett, W. D. 1904. Diptera from southern Texas with descriptions of new species. Jour. N. Y. Ent. Soc. 12: 31–5.

and mulberries, were examined but without results. Fly traps were then set up in uncultivated areas, and within 24 hours two adult *pallens* were captured. This catch proved confusing, as the traps had been set up in the midst of a burial ground for citrus culls. Trapping was continued in the vicinity and various numbers of *pallens* were captured daily. It so happened that practically all specimens captured were taken in the traps nearest the citrus pits. This and the fact that one *ludens* was also captured made the pits objects of suspicion.

A large screen cage was then built over one of the citrus pits. It was observed daily for three weeks with negative results, although traps in the immediate vicinity continued to catch the flies. The captured flies appeared to have emerged recently, as no eggs were found in the ovaries of the females.

From these observations it seemed evident that the species was breeding in wild growth. No larvae, however, were to be found in any of the wild fruits then present in the locality.

On the supposition that conditions might be different at other points, traps were set up in two other localities in the wild growth. Particular care was exercised in selecting these latter points of study in order to avoid possible specimens from citrus or vegetables. Adult *pallens* were captured in each of these places within a few days. However, as regards fruit for larvae to feed in, conditions were the same as in the original location. Only a few fruits were present and no larvae were found in them. The observations were valuable, nevertheless, in that they tended to eliminate vegetables and citrus from the list of possible hosts.

By this time several pairs of flies were being observed in the laboratory. They were confined in a screen-cloth cage and fed on orange juice and water. Oranges, grapefruit, vegetables and wild-growth fruits were kept in the cage at all times. Mating and oviposition were observed shortly after the inception of the experiment. For the latter, in every case observed, females selected a small fruit, *Bumelia spiniflora*, which is found in the uncultivated land. Field work was then concentrated on this wild plant. In the localities where so many flies had been taken the trees were not in bearing, but an examination of the soil beneath the trees revealed several empty pupal cases and a few live puparia. Adult *pallens* emerged from the puparia shortly after they were removed from the soil. In subsequent observations larvae taken from seeds of the fruit proved to be *pallens* when reared to adults.

Host.—The host, *Bumelia spiniflora*, is called locally "la coma." It is one of several species of the sapodilla family which are infested by flies of the genus *Anastrepha*. It is a shrublike bushy plant with an approximate height of 10 feet and trunk diameter of about 4 inches. The branches are usually short and pointed like thorns at the end. Thorns are usually present on the branches, although some young branches do not possess them. The leaves are small, approximately $1\frac{1}{4}$ inches long and one-half inch wide, and have a short petiole. While single leaves are common, they usually occur in clusters. Flowers are inconspicuous. The fruit when mature is bluish black, approximately one-half inch long and five-eighths inch in diameter. The pulp of the fruit surrounds a single hard

seed that is comparatively large. It contains an abundance of a sticky latexlike substance the color of milk. Fruits are produced singly or in clusters. Frequently fruit and leaves arise from the same point on the branch.

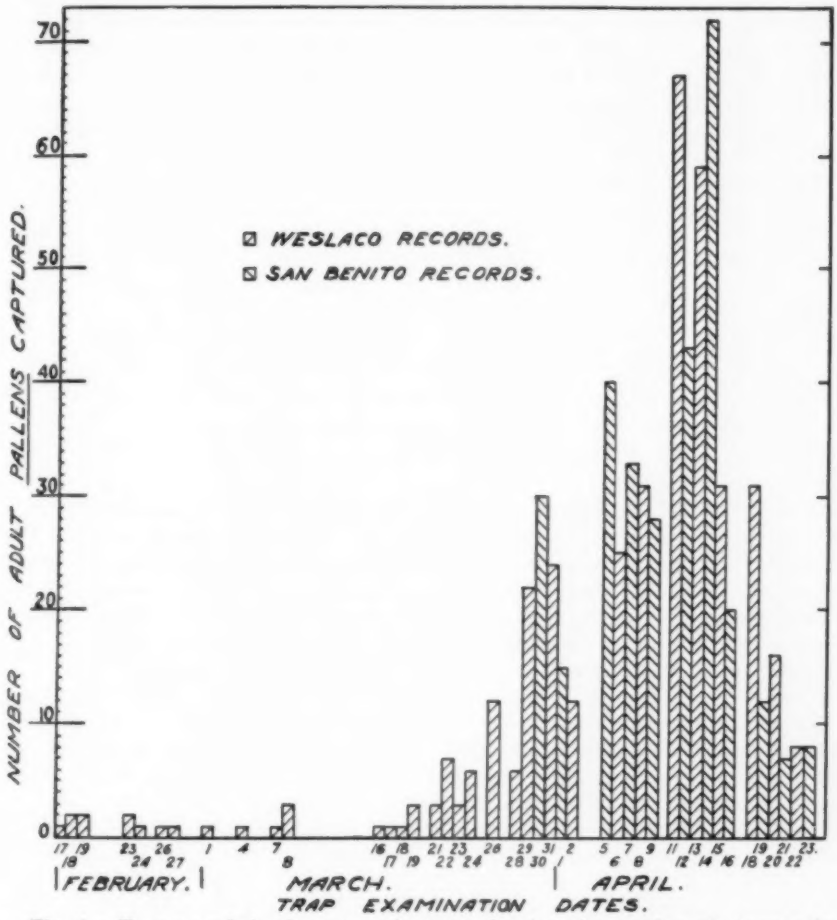

Fig. 1.—Trap records in citrus trees in 1932, showing the number of *Anastrepha pallens* taken and their dates of capture. Sundays and days on which no flies were captured appear blank. Up to March 29 the traps were examined daily. Beginning March 30 each trap was examined every other day except Sundays.

"La coma" is known to occur more or less abundantly throughout the valley. It is confined to uncultivated wild land, except in a few cases where trees have been left in the yards of dwellings. Observations tend to show that it prefers elevated, well-drained land, such as is obtained by erosion near arroyos and resacas. It thrives best when not crowded by

other plants, but it occurs also in dense growth. Overflow water from the Rio Grande has doubtless done much toward establishing the plant all over the section.

The writers know very little of the phenology of the host. At the present writing (April 12, 1932) there is an abundance of green fruit, some ripe fruit and a few blossoms. Some trees have not blossomed yet. An abundance of ripe fruit was observed in one locality in February of this year. It appears that the fruiting season covers a considerable portion of the year, with a peak in abundance of ripe fruit during spring.

General observations.—Although the writers have been concerned primarily in locating the host of *A. pallens*, some notes of a general nature have been made which will be recorded.

Mating was observed in captivity. Differing from *A. ludens* in this respect, there was no pronounced diurnal fluctuation in the function. Pairs have been observed together at all hours of the day from 8 a. m. to 6 p. m. Oviposition occurs soon after mating. In captivity females frequently simulate oviposition. Eggs are deposited singly, apparently in the seed of the host fruit when the fruit is approximately one third grown. The seeds of older fruit have a tough, impervious covering. The infested fruit remains on the tree and continues to grow without apparent injury, except for a slight exudation of latex where the puncture was made, until it drops to the ground. The larva feeds exclusively on the inner part of the seed. When mature it is surrounded by excrement. It leaves the seed by way of the stem end and enters the soil to pupate. Fruit from which larvae had already emerged have been observed on the tree, although emergence does not usually occur until the host has dropped to the ground. Pupation occurs in the first few inches of soil.

Table 1.—Larval infestation of *B. spiniflora* by *A. pallens*.

Date Fruits Were Examined	Branch No.	Number of Fruits Examined	Number of Fruits Infested
April 16	1	114	78
April 16	2	100	59
April 16	3	100	7
April 18	4	100	3
April 18	5	38	20

Adults of the species are apparently general feeders. Fig. 1 records some catches made in citrus trees. The reason for the migration to citrus, as shown in the figure, was not established, for when the traps were catching most flies in citrus, host fruits were comparatively abundant in the wild growth. At one time the writers were of the opinion that these high records covered the spring emergence from overwintering puparia. Later observations, however, tended to disprove this. Frequently only a few traps would catch flies in a grove where there were many traps set. For example, on April 11, 45 flies were captured in one orchard, 27 of which were taken in one trap. This suggests a mating reaction.

With reference to any particular locality, larval infestation is not general but spotted. Table 1 presents some typical records obtained from fruit collected near San Benito, Tex.

Ecological features of the habitat of the species.—The term "lower Rio Grande valley" is applied to a vast section in the southern part of Texas and the northeastern part of Mexico. It parallels the Rio Grande from its mouth to beyond Mission, Tex. The width of the section varies. On the American side all of Cameron, Hidalgo, and Willacy counties are included in the area.

The history of the formation of the section is similar to that of the Mississippi delta. Even now the area is subject to floods from the Rio Grande. Levees and drainage canals are maintained for the purpose of minimizing the effect of overflow on agriculture and other endeavors.

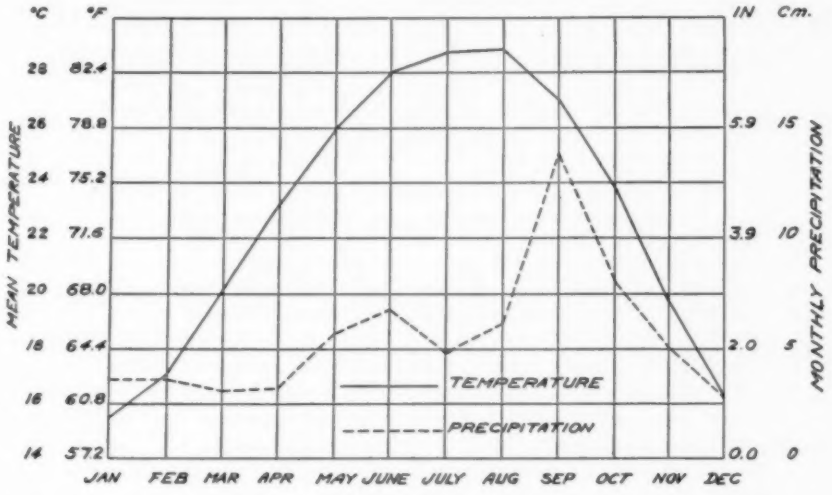

Fig. 2.—Average monthly mean (normal) temperature and average monthly precipitation in Brownsville, Tex.

The section can be conveniently divided into two types of land, namely cultivated and uncultivated. The former is devoted primarily to vegetables and citrus, but considerable cotton and some corn are grown. Uncultivated land, which is made up of prairies and growths of various kinds of wild plant life, is present in and surrounds the cultivated area. The wild plants are typical of those grown in a dry climate. Most of them have thorns. Leaves, when present, are small and often elongate, needle-like. Cactus, mesquite and ebony are common throughout the uncultivated area.

The climate of the section is semiarid and semitropical, fig. 2. It is well adapted to vegetable and citrus culture. However, irrigation water must be supplied to these crops. "Northers" are common during the winter months and are sometimes accompanied by freezing temperatures. The prevailing direction of the wind is from the southeast, off the Gulf of Mexico. The breeze is noticeable at practically all times and gives to the section a very agreeable and even climate.

Adaptation possibilities of the species.—At present *A. pallens* seems to be confined to native or wild growth. That the species might have hosts in addition to *Bumelia spiniflora* is granted. More observations are necessary to determine this. Vegetables and citrus are apparently not attacked at present. Even attempts to force oviposition in these crops were not successful. It is, of course, a matter of conjecture what the species will do in the future. The rapid growth of vegetables and citrus culture in the area at the expense of the present host plant emphasizes the possibility that the insect may turn to some cultivated crop.

COMPARATIVE TOXICITIES OF METHYL THIOCYANATE AND HYDROCYANIC ACID TO THE CALIFORNIA RED SCALE

F. H. Lathrop,[1] H. L. Cupples, Julian Hiley and H. R. Yust,
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Methyl thiocyanate, used as a fumigant, has been found to be remarkably toxic to all stages of the California red scale *Chrysomphalus aurantii* Mask.[2] Other simple aliphatic thiocyanates and isothiocyanates are also decidedly toxic to this insect, but of those tested at the Whittier, Calif., laboratory, methyl thiocyanate appears the most promising. It is generally appreciated by research workers that hydrocyanic acid is an extremely toxic material and that it is effective as an insecticide at remarkably low concentrations. Any compound that approximates hydrocyanic acid in toxicity to insects, therefore, may be regarded as being of immediate interest. On this basis methyl thiocyanate qualifies as an outstanding compound.

Its extreme toxicity to man and domestic animals is perhaps the chief disadvantage in the use of hydrocyanic acid as an insecticide. Comparative tests by the authors on albino rats showed that concentrations of methyl thiocyanate (on a molecular basis) about 10 times as great as those of hydrocyanic acid were required to kill the animals in a given period of time. In view of this great difference in toxicity to the higher animals, it is especially interesting to note, from the data shown in this paper, that the two compounds are about equally toxic to the California red scale.

Table 1 and fig. 1 present data from comparative fumigations with methyl thiocyanate and hydrocyanic acid of lemons infested with the California red scale. The exposure in each fumigation was for a period of 25 minutes, at a temperature of 25° C (77° F), the technique being identical with that described elsewhere.[2] The scale counts refer to the second molt and early gray stages only, as these stages were found to be

[1] Now entomologist, Maine Agricultural Experiment Station.
[2] Cupples, H. L., H. R. Yust and Julian Hiley. Tests of possible substitutes for hydrocyanic acid in the fumigation of the California red scale. Unpublished MS.

the ones most resistant to toxic gases. No correction was made for the 4 to 5 per cent natural mortality indicated by the counts of unfumigated lemons, since this was not sufficiently great to change the data materially.

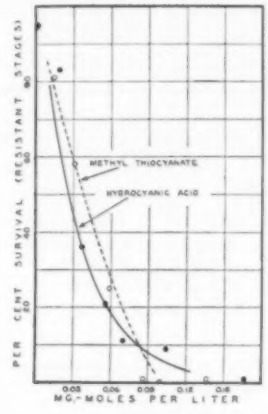

Fig. 1.—Comparative toxicities to California red scale of methyl thiocyanate and hydrocyanic acid. All fumigations for 25 minutes at 25° C (77° F). Red scale from vicinity of Fullerton, Calif.

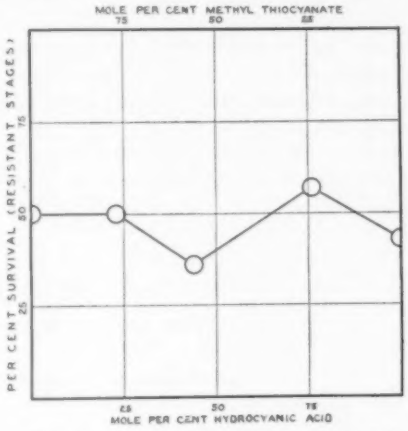

Fig. 2.—Comparative toxicities to California red scale of methyl thiocyanate, hydrocyanic acid, and their mixtures, at a constant total molar concentration. All fumigations for 25 minutes at 25° C (77° F). Red scale from Corona, Calif.

The scale-infested lemons used in these tests were from the vicinity of Fullerton, Calif. The concentrations of the fumigant were expressed in milligram-moles per liter as well as in milligrams per liter, in order to

Table 1.—Comparative toxicities of methyl thiocyanate and hydrocyanic acid to the California red scale.

Fumigant	Date of Treatment	Concentration of Fumigant		Scale Survival
		Mg. per liter	Mg.-moles per liter	Per cent
Methyl thiocyanate	4-4-33	1	.014	81
	4-4-33	2.3	.031	58
	4-4-33	4.3	.059	25
	4-4-33	6.3	.086	1
	4-4-33	7.3	.1	0
	4-4-33	10	.137	1
Not fumigated				95
Hydrocyanic acid	4-5-33	.5	.019	83
	4-5-33	1	.037	36
	4-6-33	1.5	.056	21
	4-6-33	1.9	.07	11
	4-6-33	2.8	.104	9
	4-6-33	4.5	.167	1

show the remarkable similarity between the toxic effects of the two compounds when compared molecule for molecule. On this basis the two compounds are evidently about equally toxic, with methyl thiocyanate appearing to be the more efficient in killing the most resistant individuals.

Another series of experiments was conducted to compare the toxicity of methyl thiocyanate, hydrocyanic acid, and mixtures of the two, at the constant total concentration of .071 milligram-mole per liter. In these experiments also each fumigation was for a period of 25 minutes, at a temperature of 25° C (77° F). The scale counts included the second molt, early-gray and late-gray stages only, and a representative count included about 500 scales, as in the previous series. Lemons for these tests were obtained from the vicinity of Corona, Calif. Inspection of the data as given in table 2, and especially in fig. 2, shows each compound and each of the mixtures about equally toxic to the scale, when the concentrations are expressed on a molecular basis. It will be observed (table 2) that the actual total molecular concentrations were not strictly constant, but since the observed variations in scale mortality were opposite to what would be expected from the variations in concentration it appears that these variations in concentration were not important.

Table 2.—Comparative toxicities to the California red scale of methyl thiocyanate, hydrocyanic acid, and their mixtures.

Date of Treatment	Concentration of Hydrocyanic Acid		Concentration of Methyl Thiocyanate		Total Concentration	Hydrocyanic Acid	Scale Survival
	Mg. per liter	Mg.-mols per liter	Mg. per liter	Mg.-mols per liter	Mg.-mols per liter	Mole Per cent	Per cent
6-15-33	1.9	.071	0	0	.071	100	43
6-15-33	1.43	.053	1.22	.017	.07	76	57
6-15-33	.81	.03	2.79	.038	.068	44	36
6-15-33	.48	.018	4.3	.059	.077	23	50
6-14-33	0	0	5.15	.071	.071	0	50
Not fumigated							96

The data here presented demonstrated that the vapor of methyl thiocyanate as a fumigant is remarkably toxic to the California red scale. Molecule for molecule, it is equally as toxic as hydrocyanic acid. In selecting a fumigant for the fumigation of trees, however, other important factors must be taken into consideration. The fumigant should preferably be readily volatile, although it might be found possible to overcome some deficiency in respect to volatility, and it is a fundamental requirement that a dosage sufficient to kill the scale shall not cause excessive injury to the tree. In each of these respects methyl thiocyanate is probably inferior to hydrocyanic acid. It is much more difficult to volatilize, and small-scale tests on young citrus trees indicated that it is too injurious to the trees for successful fumigation. The studies of the effects upon the plant tissues are not definitely conclusive, however.

Aside from the bearing upon the problem of control of the California red scale, the studies here reported have some general interest because of the attention being given by other investigators to the value of the thiocyanates as insecticides.

NOTES ON THE WARRIOR GRASSHOPPER *CAMNULA PELLUCIDA* (SCUDDER)

AND ITS EGG PARASITE *APHOEBANTUS HIRSUTUS* COQUILLETT, IN NORTHERN CALIFORNIA, 1928–29

C. C. Wilson,[1] *U.S.D.A., Bureau of Entomology and Plant Quarantine*

Severe outbreaks of the warrior grasshopper *Camnula pellucida* (Scudder), with attendant severe damage to cereal and forage crops, have occurred regularly each season since 1922 in the Tule lake district of Siskiyou and Modoc counties, Calif., and in adjacent areas in Klamath county, Ore. The Tule lake basin is a fertile irrigated area of approximately 45 square miles, a former lake bed, with an elevation of 4300 feet, producing large crops of alfalfa, potatoes and cereals. The soil is of sedimentary origin, ranging from a peat composition to pure sand. The rim of the old lake bottom is of sandstone and granite, and the level of the lake area is broken by elevated areas of sand and rock.

The breeding grounds of the warrior grasshopper in the Tule lake district were reduced from 5000 acres of dense egg beds in 1927 to local and sparse beds in 1929. The grasshopper populations on these breeding grounds were reduced by the widespread use of poisoned bran acting together with the natural enemies. Although there is no doubt that the egg parasite *Aphoebantus hirsutus* Coquillett has been an important factor in the control of grasshoppers in this district, the value of the parasite in any one season had not been computed prior to 1928—hence the present study.

The problem and method of attack.—The problem embraced the study of the general life history and habits of the warrior grasshopper, and the study of the bombyliid fly *Aphoebantus hirsutus* in relation to the type of soil and vegetation frequented by it and its parasitization of the grasshopper egg capsules. Observations were made during the fall of 1928 to determine the number of egg capsules in a given area and the distribution of *A. hirsutus* in the egg beds. The following spring the number of grasshoppers on the egg beds and the time of emergence of the parasite were noted.

Areas of one square yard each were used as units in determining populations. From four to seven such squares of soil were examined on the egg-bed areas under observation. The number of squares examined on each area depended on the size of the egg bed and on the abundance of the grasshopper egg capsules. The soil in each square yard was sifted through wire sieves, first through one of eight-mesh and then through one of 14-mesh screen. The egg capsules and free parasitic larvae found were then placed in cartons and brought to the laboratory for examination.

Biology of *Camnula pellucida*.—*Camnula pellucida* is found in moun-

[1] The writer is indebted to W. B. Cartwright and R. A. Blanchard of the U.S.D.A., Bureau of Entomology and Plant Quarantine, Division of Cereal and Forage Insect Investigations, for suggestions and aid in the preparation of the manuscript.

tain meadows, foothills and valleys throughout northern, central and coastal California, in the transition and humid-transition life zones. It is of economic importance at elevations from sea level to 5000 feet above. Oviposition usually begins the latter part of July and continues to the end of August. This grasshopper differs from other species observed in California in that it has definite oviposition areas and goes back and forth between 10 a. m. and 3 p. m. between these areas and the feeding grounds. These oviposition areas are usually on uncultivated knolls of sand and rock along the rim of the lake, but may be also in cultivated fields.

The method of mating is unique in that the male inserts its abdomen into the soil beside that of the ovipositing female. As many as 10 males may attend one female, and this congregating of the males around the ovipositing females aids in the location of the egg beds. These definite oviposition areas may be marked off for identification, and observations made the following spring on the time of hatching and migration of the grasshoppers into field crops.

The period of hatching in the mountain meadows varies according to climatic conditions, but usually extends from early in May to the latter part of June. Locating the egg-bed areas in the fall is an important factor in control, as poisoned-bran bait may be applied to these oviposition areas before the third-instar nymphs migrate to field crops.

Preparatory to the more intensive study of the relation of *A. hirsutus* to *C. pellucida* in the Tule lake district it became necessary to determine the approximate number of eggs per capsule of this species of grasshopper in order to determine the value of the parasite. Dissection of 104 capsules from a random sample of 1547 showed a total of 2886 eggs, or an average of $27.75 \pm .26$, the number per capsule ranging from 16 to 36 with a standard deviation of 3.99.

***Aphoebantus hirsutus* as an enemy of *C. pellucida*.**—*Aphoebantus hirsutus* was described by Coquillett[2] in 1886, from specimens collected in northern California. It is a small bombyliid fly. The adult is slender, 7 to 8 mm. in length, its ground color black and its body clothed with yellowish pile. This species is associated with the egg beds of the warrior grasshopper in the mountain meadows of Siskiyou, Modoc, and Lassen counties in northern California.

In the Tule lake district, 54 acres of grasshopper egg beds were under observation for the study of *A. hirsutus* and its effectiveness in diminishing the numbers of egg capsules of *Camnula pellucida*. For convenience of observations the egg beds were numbered 1 to 7, and these comprised approximately 2, 5, 12, 20, 3, 8 and 4 acres, respectively. The types of soil in the different egg beds examined may be classified as follows: the soil of egg beds 1, 3, and 7, located on the lake bed proper, was of a peaty composition with moisture near the surface; egg bed 2 was a distinct type of soil made up of sand and gravel with a heavy mat of tule grass; and egg beds 4, 5 and 6 were located above the lake bed in rocky and sandy areas having sparse vegetation. The status of *A. hirsutus* on representative areas examined in the Tule lake district is given in table 1.

[2] Can. Ent. 18: 81–7. 1886.

Table 1 shows that the number of egg capsules of the warrior grasshopper on each area of one square yard was far from uniform. More heavily populated areas, both of grasshopper egg capsules and of parasitic larvae, were usually encountered in moist peat and sandy loam soils

Table 1.—Parasitization of egg capsules of *Camnula pellucida* by *Aphoebantus hirsutus* in 1928.

Egg Bed no.	Sample No.[1]	No. Egg Capsules Recovered	No. Capsules Found Parasitized	No. Unconsumed Eggs in Parasitized Capsules	No. Parasites in Capsules	No. Capsules from Which Parasites Emerged	No. Parasites in Soil	Total No. Parasites Recovered	Per Cent Proved Parasitization	Per Cent Probable Parasitization
	1	11	4	71	1	3	10	11	36.4	61.1
	2	207	102	980	69	33	89	158	49.3	60
1	3	147	47	413	32	15	64	96	32	48.9
	4	51	8	94	6	2	8	14	15.7	24.6
	5	65	15	95	7	8	17	24	23	32.4
	Average	*96.2*	*35.2*	*330.6*	*23*	*12.2*	*37.6*	*60.6*	*36.6*	
	1	117	66	487	26	47	292	318	56.4	85.9
2	2	24	22	7	6	17	81	87	91.7	97.7
	3	18	18	0	12	10	60	72	100	100
	4	75	40	215	9	43	96	105	53.3	72.7
	Average	*58.5*	*36.5*	*177.2*	*13.2*	*29.2*	*132.2*	*145.5*	*62.4*	
	1	8	4	26	1	3	5	6	50	60
	2	2	1	5	0	1	2	2	50	66.6
3	3	41	18	83	4	14	95	99	43.9	81.1
	4	7	2	4	1	1	6	7	28.6	58.3
	5	2	1	8	1	0	0	1	50	50
	Average	*12*	*5.2*	*25.2*	*1.4*	*3.8*	*21.6*	*23*	*43.3*	
	1	4	1	7	0	1	0	0	25	25
	2	2	0	0	0	0	0	0	0	0
	3	17	0	0	0	0	2	2	0	10.5
4	4	2	2	9	0	2	6	6	100	100
	5	0	0	0	0	0	0	0	0	0
	6	399	0	0	0	0	29	29	0	6.7
	7	2	0	0	0	0	0	0	0	0
	Average	*60.9*	*.4*	*2.3*	*0*	*.4*	*5.3*	*5.3*	*.7*	
	1	8	0	0	0	0	0	0	0	0
	2	130	2	17	1	1	1	2	1.5	1.5
	3	4	0	0	0	0	0	0	0	0
	4	141	21	176	2	19	64	66	14.9	35.5
	5	3	0	0	0	0	0	0	0	0
	6	1	0	0	0	0	0	0	0	0
	7	3	0	0	0	0	11	11	0	78.6
	Average	*41.4*	*3.3*	*27.6*	*.4*	*2.8*	*10.9*	*11.3*	*7.9*	
	1	7	0	0	0	0	1	1	0	12.5
	2	2	1	9	0	1	1	1	50	50
6	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0
	Average	*1.8*	*.2*	*1.8*	*0*	*.2*	*.4*	*.4*	*10*	
	1	12	2	16	0	2	11	11	16.7	52.4
	2	5	3	20	0	3	16	16	60	88.9
7	3	2	1	17	0	1	14	14	50	93.3
	4	12	2	13	0	2	4	4	16.7	28.5
	5	16	1	7	0	1	7	7	6.3	31.8
	Average	*9.4*	*1.8*	*14.6*	*0*	*1.8*	*10.4*	*10.4*	*19.1*	

(egg beds 1, 2 and 3) where weeds and grass were present than in arid areas of sand and rock where there was sparse vegetation (egg beds 4, 5 and 6). The scarcity of the parasite on the latter area was probably due both to the arid condition and to the texture of the soil. In every parasitized egg capsule examined that contained *Aphoebantus* larvae there

[1] Each sample contained the egg capsules and parasites collected in an area of 1 square yard.

remained a number of unconsumed grasshopper eggs. In every case where these egg capsules were saved the remaining eggs failed to hatch in the following spring.

The number of grasshopper eggs destroyed was probably greater than would be indicated by the parasitized capsules found. The free-living larvae found in the soil evidently came from destroyed capsules the identity of which was lost in the process of removing and sifting the earth. The majority of capsules examined contained but one *Aphoebantus* larva. Where more were found, only one had developed, the remaining larvae being undeveloped and, in most cases, dead.

Using as an example the first line of table 1, and assuming that three of the 10 free, living parasites came from the three capsules found empty (column 7), there are still seven that represent disintegrated capsules evidently destroyed in the sifting of the material; so that there must have been, in addition to the 11 capsules found, at least seven more, or a minimum of 18 capsules in the square-yard sample. As 11 parasites were found, a probable parasitization of 61.1 per cent is indicated, as shown in the last column.

Granting that as many free-living larvae migrate to the 1-square-yard areas as move from them, it is believed that this probable percentage of parasitization is a better index to the actual number of egg capsules parasitized than the proven percentage of parasitization.

The value of *Aphoebantus hirsutus* as an aid in the reduction of the population of grasshoppers has been strikingly shown in this study. In areas where heavy attack was noted in the fall, the number of grasshoppers hatching the following spring was negligible. It was only in the lightly attacked areas (egg beds 4 and 5) that grasshoppers were in sufficient numbers to warrant control measures. Where a small number of egg capsules were present on the egg-bed areas and the degree of attack exceeded 8 per cent (egg beds 6 and 7), the number of grasshoppers that hatched was so decreased that no damage resulted to field crops. In fact, control measures by means of poisoned bran bait were necessary only on egg beds 4 and 5 in 1929.

Summary.—The warrior grasshopper *Camnula pellucida* occurs in injurious numbers in California only in the transition and humid-transition life zones. Definite oviposition beds are adopted, and the grasshoppers go from these to green vegetation to feed and back again to the original locations for oviposition.

Moist peat and sandy loam soils are apparently preferred for oviposition grounds, though this preference is not very marked. Oviposition beds once established on any type of soil, however, become permanent.

Eggs hatch over a period of approximately two months, and the young grasshoppers remain in the area of the egg bed until the third instar.

Aphoebantus hirsutus attacked from .7 to 62.4 per cent of the grasshopper egg capsules in the various egg beds in the Tule lake district in 1928, and was an important control factor, especially in the cases of egg beds on peat or sandy loam soils.

LABORATORY TESTS WITH IMPREGNATED OIL AS CODLING MOTH LARVICIDES

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The general use of refined petroleum oil as an ovicide in sprays for the codling moth, *Cydia* (*Carpocapsa*) *pomonella* L., which contain lead arsenate, nicotine sulfate or other larvicides, has indicated the possibility of impregnating the oil with some toxic agent to increase its larvicidal efficiency. With this object in view, an investigation was made of some of the available chemical compounds to determine their toxicity to codling moth larvae when they were mixed with refined petroleum oil.

Review of literature.—McAllister & Van Leuwen (2) surveyed the toxicity of 284 materials to newly hatched codling moth larvae. At 10 per cent concentration in talc dust diphenylamine, 2–4 dinitrotoluene, 2–4 dinitrophenol, 3–5 dinitro-o-cresol, alpha naphthylamine and beta chloro-ethyl-p-toluene sulfonate almost equalled or exceeded the percentage of efficiency of 10 per cent acid lead arsenate in talc dust. The liquids, acid lead arsenate—4 pounds to 100 gallons of water—dinitrobutylcyanamide, beta chloro-ethyl-p-toluene sulfonate, dibenzylamine, ethyl benzyl-o-toluidine, ethyl thiocyanate, methyl alpha naphthylamine, and n-propyl-p-toluene sulfonate—at 10 per cent in talc dust—gave between 90 and 100 per cent efficiency.

Newcomer & Yothers (*3*) reported lead arsenate the most effective of 12 arsenates tested. Zinc arsenite was slightly more effective than any other arsenical. Nicotine sulfate mixed with oil emulsion was the most effective of the other materials tested.

Materials and methods.—Small Ben Davis apples were cleaned of all spray residue and the cavities around the stem and calyx were sealed with paraffin. A paper clip attached to a tag by a string was thrust into the stem end of each apple before the paraffin was applied.

An unemulsified refined petroleum oil was used. The specifications of this oil were specific gravity .857, flash point 174° C, fire point 202° C, Saybolt viscosity at 38° C 83 seconds, amount absorbed by sulfuric acid 1 per cent, evaporation 0 per cent, acidity in mg. of KOH per gram of oil .014. The oil was impregnated with the various materials simply by mixing them. If the material did not go into solution in the oil a fairly stable suspension was prepared by grinding the solid materials or thoroughly mixing the liquids and the oil. The suspensions were not permitted to separate during application to the apples.

The impregnated oil was applied to rotating apples by an atomizer that delivered 1.18 cc. of oil during the 20-second period of the spraying operation. A differential manometer was used to obtain a uniform flow of compressed air through the atomizer. The spraying was done at temperatures that ranged from 18 to 24° C.

[1] Formerly associate entomologist, Illinois Natural History Survey, Urbana, Ill. This paper is a contribution from Illinois Natural History Survey project 9.1.

After the oil was applied the apples were stored at room temperature for 24 hours before they were infested. Ten newly hatched codling moth larvae were transferrred to each apple and the infested fruit placed in a constant temperature unit at 26.7° C and 50 per cent relative humidity for 24 hours. The larvae were produced by the method of Farrar & Flint (*1*).

During the 24-hour period after infestation all the larvae not killed by the spray treatment entered the fruit. The apples were then stored in a greenhouse at 18 to 30° C for five days. At the end of this period the number of stings and entries in each apple was recorded. If a larvae had

Table 1.—Impregnated oil as a codling moth larvicide.

Item No.	Material Added to Oil	Percentage by Weight Added	Average Entries per Apple	Percentage of Control of Entries
1	Nicotine sulfate	2	0	100
2	Nicotine sulfate	1	.2	96
3	Methyl salicylate	2	1.3	71
4	Para dibromobenzene	20	1.7	61
5	Naphthalene	10	1.7	61
6	Copper cyanide	2	1.8	59
7	Copper oleate	2	1.8	59
8	Ground pyrethrum	15	2	55
9	Alpha naphthylamine	2	2	55
10	Iodine	2	2	55
11	Beta iodonaphthalene	2	2	55
12	Nicotine sulfate	.4	2.1	52
13	Meta dinitrobenzene	2	2.2	50
14	Control (nothing added to oil)		4.4	0

penetrated less than one-fourth of an inch into the apple the injury was considered as a sting, if the living insect was not found. If the hole was more than one-fourth of an inch deep or living larvae were found, the injury was counted as an entry.

As this study was intended to be only a preliminary survey of a large number of compounds of doubtful value, only from 30 to 210 larvae were used to test any one mixture. The average was 55 larvae exposed to each treatment.

Apples sprayed with this unemulsified refined petroleum oil with nothing added to it were used as the control. This application of oil killed about 35 per cent of the larvae that would have entered unsprayed apples. Thirteen hundred larvae were used in the control treatment.

The percentage of control of entries was calculated by the method suggested by the Insecticide and Fungicide Board of the U. S. Bureau of Entomology and Plant Quarantine (*4*).

Results.—As this study was a preliminary survey of possible toxic agents to add to refined petroleum oil to kill codling moth larvae, no discussion of the stings made by the larvae will be included, but only the entries or worm survival will be considered. In the results obtained only a few materials showed marked toxicity to the larvae. The majority of the mixtures were little if any more injurious to the larvae than the oil alone. The most toxic materials are listed in table 1.

The materials and percentage of them mixed with the oil that gave between 48 and 41 per cent control of entries are:

dibromo-o-cresol	1	carbon tetrachloride	1
p-chloro-aniline	2	piperine	2
p-nitro-iodobenzene	2	toluene	2
3–5 dibromo-o-cresol	5	o-toluidine	2
xylene	2	thymol	2
allyl isothiocyanate	1	o-dichlorobenzene	2
beta chloronaphthalene	2	iodine	1
3–5 dibromo-o-cresol	2		

Oil impregnated with the following materials gave between 40 and 25 per cent control of codling moth entries:

fluorbenzene	2	monochloronaphthalene	2
beta iodonaphthalene	20	copper sulfocyanide	2
barium stearate	1	rotenone	1
aniline	2	o-nitrochlorobenzene	2
p-di-iodobenzene	10	barium oleate	1
tetrachloro-ethylene	20	p-dibromobenzene	1
2–4 dichloro-6-phenylphenol	2	benzene	2
alpha nitronaphthalene	2	1 nitro-2-naphthol	2
p-nitrochlorobenzene	2	sodium arsenite	1
2–5 dichloro-aniline	2	benzyl arsenic acid	2
1–2–4–5 tetrachlorobenzene	1	thallous malonate	2

The remaining mixtures gave less than 25 per cent control of entries and were considered as practically nontoxic. In fact, about the last third of this group actually gave a negative percentage of control, as they had an average of more than 4.4 entries per apple. The materials in the oil in this group are:

sodium cyanide	1	beta naphthol	1
naphthalene	2	2 chloro-6-phenylphenol	2
m-dichlorobenzene	1	3–5 dinitro-o-cresol	1
phenol	2	anthracene	1
trinitroresorcinol	1	cumidine	2
copper oleate	5	chloro-acetone	1
o-phenylphenol	2	1–3–5 trinitrobenzene	1
9–10 dichloro-anthracene	1	2–4 dichlorophenol	1
menthol	2	p-nitro-aniline	1
p-dichlorobenzene	10	beta chloro-ethyl-p-toluene sulfonate	1
sodium sulfocyanide	1	bromo beta naphthol	1
dinitrophenol	1	carbon disulfide	2
sodium o-phenylphenylate	2	iodoform	1
phenyl isothiocyanate	1	sodium fluoride	1
triphenylarsine	1	chloropicrin	1
beta bromonaphthalene	2	bromopicrin	1
dichloronitrobenzene	1	bromine	1
p-p-dichlorodiphenol	1	chlorine	2
o-cresol	2		

nitrobenzene	2	beta bromonaphthalene	20
beta iodonaphthalene	1	chloroform	10
pyridine	2	phenacyl chloride	2
sodium chloro-o-cyclohexyl-phenate	2	dibromonaphthalene	1
p-dimethyl aminobenzyl aldehyde	2	diphenyl amino-arsine	2
cyanamide	2	p-di-iodobenzene	1
tetrachloro-ethylene	1	2–4 dinitrochlorobenzene	2
bromoform	1	arseneous oxide	1
beta chloronaphthalene	20	cyanogen bromide	1
1–2–4 trichlorobenzene	1	cetyl alcohol	2
dinitronaphthalene	1	metallic arsenic	1
phenyl alpha naphthalamine	1	p-bromobenzonitrile	1
o-cyclohexylphenol	2	beta naphthylamine	2
		p-nitrobromobenzene	2
		p-toluidene	1

Discussion.—In general the investigation was directed toward a comparison of compounds that contained copper, iodine, chlorine or bromine and compounds that contained the benzene or naphthalene structure. In addition to these compounds many other materials were tested. Nicotine sulfate (40 per cent of Black Leaf 40) was taken as a standard material of known toxicity.

The nicotine sulfate—oil mixtures were the most toxic.

Mixtures containing copper were generally toxic with copper cyanide the most toxic of this group. Copper oleate was fairly toxic at 2 per cent in the oil but only slightly toxic at 5 per cent. Several other materials that were toxic at 2 per cent in the oil showed little increase in toxicity at 10 or even 20 per cent concentrations and some were even less toxic when more of the material was added to the oil. The number of compounds tested and the number of tests run on each compound were too few to draw any general conclusions as to the relation of chemical structure and toxicity. However, considering only the materials tested, the mixtures containing iodine, chlorine and bromine ranked in the order listed in toxicity to the larvae. The mixtures containing the naphthalene group were slightly more toxic than those containing the benzene group. Anthracene and 9–10 dichloro-anthracene were practically nontoxic.

Summary.—About 100 materials were mixed with a refined petroleum oil and tested in the laboratory for their toxicity to newly hatched larvae of codling moth, *Cydia* (*Carpocapsa*) *pomonella* L. Of the mixtures tested, nicotine sulfate, methyl salicylate, copper cyanide, copper oleate, alpha naphthylamine and iodine were the most toxic at concentrations of 2 per cent or less in the oil.

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EFFECTIVENESS OF SODIUM FLUORIDE, ARSENIC TRIOXIDE AND THIODIPHENYLAMINE AS FOOD POISONS FOR THE FIREBRAT

THERMOBIA DOMESTICA (PACKARD)

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Control of the firebrat *Thermobia domestica* (Packard) has received little study as a specific problem. Writers, in recommending control methods for the silverfish *Lepisma saccharina* Linnaeus, have frequently indicated that the same methods (usually flour paste with an arsenical) should control the firebrat. The first contribution to the control of the firebrat, as such, which was based on extensive experiments, was published by Wakeland & Waters (1931) at the University of Idaho. After making a thorough investigation of the food preferences of insects of this species they recommended a food basis for poisoned baits composed of ground oatmeal and small percentages of sucrose and common salt. In their poison experiments the firebrats, instead of being driven to eat the poisoned food or starve, had access to both poisoned and unpoisoned food. Thus their comparisons of poisons were probably influenced both by toxicity and by repellence. White arsenic (arsenic trioxide) evidently combined low repellence with satisfactory toxicity and a bait was recommended in which white arsenic formed about 7 per cent of the weight.

Mr. G. J. Spencer of the University of British Columbia, in an unpublished thesis (1924) from which he kindly permits the authors to quote, reported upon a series of tests in which firebrats were confined in pairs in Petri culture dishes with flour variously poisoned with white arsenic, calcium arsenate, lead arsenate, sodium fluoride and many others. As a result of his tests he recommended a mixture consisting of flour 100 parts and sodium fluoride 12 parts. He named calcium arsenate as second in effectiveness.

It should be noted that in Spencer's tests the insects were closely confined with poisoned food in powdered form so that contact toxicity, which is reported to be considerable with sodium fluoride, had a greater opportunity to influence results than it is likely to have in the household, where the insects are free to visit and leave the bait. It should also be noted that in the tests made by Wakeland & Waters the insects again were under conditions differing in an important respect from those in the household: they were free to choose between poisoned and unpoisoned, preferred food. Repeated studies have shown that the materials which firebrats eat under pressure of starvation, such as paper-glaze, glue, silks and woolens can scarcely be called foods at all, since they do not eat them in the abundant presence of flour or rolled oats. It is probable that, under the conditions usually found in a household, firebrats will

[1] The authors are indebted to Dr. C. H. Richardson, under whose direction this investigation was conducted, in the Department of Zoology and Entomology, Iowa State College, Ames.

eat their preferred food even when it is rendered fairly unpalatable by a poison rather than continue in semistarvation upon greatly inferior materials. For these reasons the authors determined to set up parallel series of tests in which contact effects would be minimized and in which

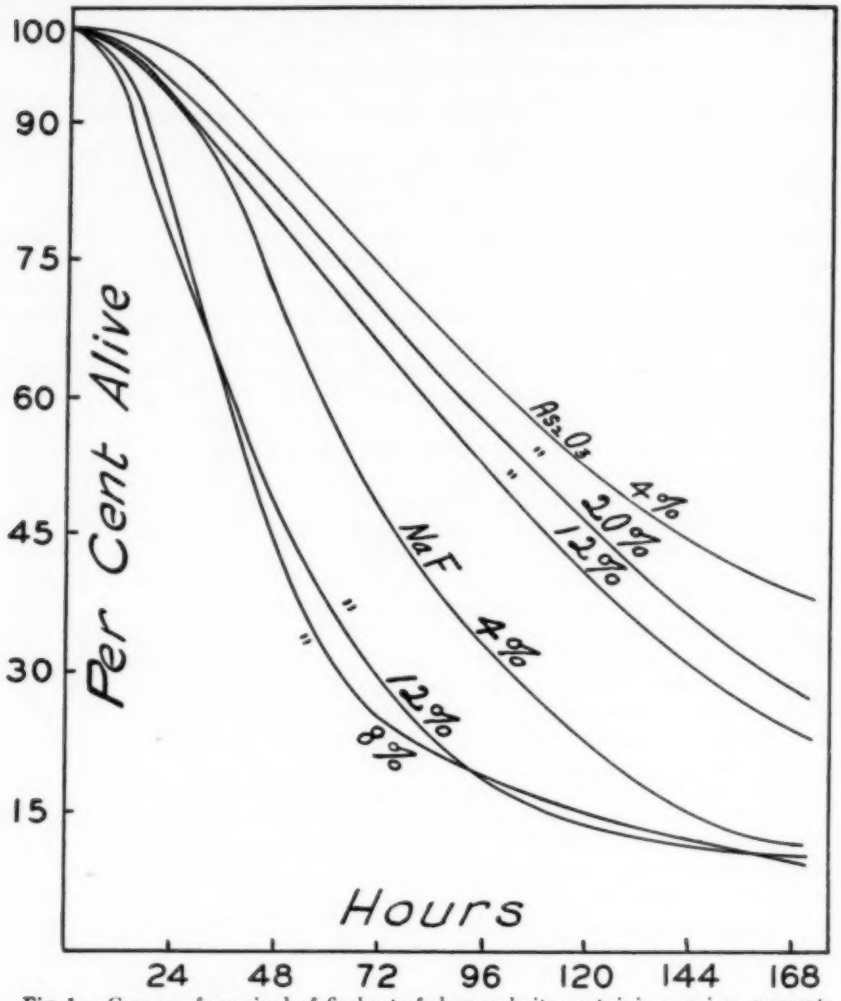

Fig. 1.—Curves of survival of firebrats fed upon baits containing various percentages of arsenic trioxide and sodium fluoride.

the insect would have access to poisoned, but not to unpoisoned, preferred food. The study of relative repellence of poisons in the preferred food constitutes a separate series of tests. (See last paragraph.)

The thiodiphenylamine used in these experiments was submitted by Du Pont de Nemours and Company to Dr. C. H. Richardson and tested

upon the firebrat at the suggestion of the latter. This new compound has proved extremely toxic to mosquito larvae (JOUR. ECON. ENT. 27:1185).

The firebrats used in the present study were mature animals less than one year of age reared and kept at temperatures near 34.5° C in open culture dishes in gently moving air at a relative humidity of about 70 per cent. Further details upon the firebrat are published elsewhere (*1*, *3*).

Methods in determining effectiveness of the three poisons.—The firebrats were kept individually in 25 by 50 mm. shell vials throughout the period of the trials. Direct contact with the mixtures was partially eliminated by the presence of folded paper three-fourths of an inch high in the bottoms of the vials. The paper served as a perch from which the insect could descend to feed on the mixture in the bottom of the vial. They were never handled directly but were dropped from one vial to another or guided into the vials with a camel's-hair brush. All test and control individuals were kept at a constant temperature of 34.5° C in gently circulating air of about 70 per cent relative humidity. All insects were starved for 24 hours immediately preceding the beginning of the trials. Failure to respond to pinching of the tarsi, cerci or antennae served as the criterion of death.

Materials tested for toxicity in varying concentrations were intimately ground into a bait of the following composition:

Rolled oats (finely ground)	100 gm.
Cane sugar (powdered)	5 gm.
Salt (table grade, finely ground)	2.5 gm.

The oats used were a product of the Quaker Oats Company and were labelled "White Rolled," a brand for five-minute cooking.

Sodium fluoride (C. P.) was finely ground and mixed into the above bait in concentrations of 4, 8 and 12 per cent by weight.

Powdered arsenic trioxide (C. P.) and thiodiphenylamine were likewise used in the above bait in concentrations of 4, 12 and 20 per cent by weight.

Approximately .03 gram of the poisoned mixture was placed in the bottom of the vial, allowing an amount much in excess of that likely to be consumed by the insect.

A number of the insects were allowed to feed upon unpoisoned bait and an equal number continued starving during the tests. These served as controls, none of which died.

Deaths counts were made at eight-hour intervals and each series of trials was continued for 168 hours.

Forty tests were made in which the insect in the vial was given no paper to perch upon but was kept in continuous contact with the poisoned mixture.

Results.—The results of the tests with arsenic trioxide and sodium fluoride are shown in the accompanying tables and graph. The curves represent the relative effectiveness of these two compounds. Each curve shows the results obtained from testing 100 firebrats (in three groups of 20, 30 and 50 individuals, respectively) under similar conditions. A weighted average percentage of the number left alive was computed and

a moving average calculated, using numbers in series of three. A trend curve was then drawn by inspection through the points thus obtained.

Table 1.—Decline in numbers of firebrats confined with food containing various percentages of sodium fluoride. The figures are percentages of insects alive according to the indicated hours of exposure.

Hours	Sodium Fluoride 4 Per Cent				Sodium Fluoride 8 Per Cent				Sodium Fluoride 12 Per Cent				
	20 Indiv.	30 Indiv.	50 Indiv.	Wtd. Ave.	20 Indiv.	30 Indiv.	50 Indiv.	Wtd. Ave.	20 Indiv.	30 Indiv.	50 Indiv.	Wtd. Ave.	Contact
8	100	100	100	100	100	100	100	100	100	100	100	100	100
16	95	100	98	98	85	93.3	88	89	90	93.3	88	90	73.3
24	85	96.7	94	93	80	83.3	70	76	70	80	76	76	73.3
32	85	93.3	88	89	75	76.6	62	69	55	63.3	68	64	40
40	65	86.7	76	77	60	53.3	50	53	55	50	50	51	33.3
48	55	83.3	72	72	55	40	44	45	55	50	42	47	26.7
56	55	76.7	62	65	50	26.7	28	32	50	46.7	36	42	20
64	45	53.3	54	52	45	16.7	26	27	45	36.7	28	33	20
72	40	50	46	46	40	16.7	24	25	40	26.7	22	29	20
80	35	43.3	42	41	40	13.3	24	24	40	23.3	18	24	20
88	35	40	34	36	40	6.7	20	20	40	20	16	22	13.3
96	35	36.7	28	32	40	6.7	18	19	35	20	10	18	6.7
104	35	36.7	26	31	40	6.7	12	16	35	20	8	17	6.7
112	20	36.7	22	27	35	6.7	12	15	35	16.7	8	16	6.7
120	15	26.7	20	21	35	6.7	12	15	35	13.3	6	14	6.7
128	15	23.3	18	19	30	6.7	12	14	30	10	6	12	0
136	15	20	18	18	25	6.7	12	13	25	10	6	11	
144	15	16.7	16	16	25	6.7	12	13	25	10	6	11	
152	15	10	16	14	20	6.7	10	11	25	10	6	11	
160	15	10	12	12	20	3.3	8	9	25	10	4	10	
168	15	10	8	10	20	3.3	6	8	20	10	4	10	

It is interesting to note that two curves—one calculated from the results of 100 insects tested with 4 per cent sodium fluoride and the other from the first 50 animals of these trials—when superimposed, fit almost perfectly. This would seem to indicate that enough experimental animals were used to give significant results.

Table 2.—Decline in numbers of firebrats confined with food containing various percentages of arsenic trioxide. The figures are percentages of insects alive according to the indicated hours of exposure.

Hours	Arsenic Trioxide 4 Per Cent				Arsenic Trioxide 12 Per Cent				Arsenic Trioxide 20 Per Cent			
	20 Indiv.	30 Indiv.	50 Indiv.	Wtd. Ave.	20 Indiv.	30 Indiv.	50 Indiv.	Wtd. Ave.	30 Indiv.	70 Indiv.	Wtd. Ave.	Contact
8	100	100	100	100	100	100	100	100	100	98.6	99	100
16	100	100	98	99	95	90	100	96	100	98.6	99	100
24	95	100	98	98	90	90	92	91	93.3	91.4	92	100
32	95	96.7	98	97	90	80	90	87	90	90	90	93.3
40	95	73.3	92	87	90	70	84	81	80	85.7	84	66.7
48	95	70	92	86	90	70	84	81	66.7	85.7	80	66.7
56	95	66.7	84	81	85	63.3	82	77	63.3	82.8	77	46.7
64	95	56.7	80	76	65	50	80	68	56.7	78.5	72	33.3
72	95	53.3	78	74	65	50	80	68	56.7	77.1	71	26.7
80	95	53.3	78	74	60	36.7	80	63	53.3	77.1	70	26.7
88	95	40	72	67	55	36.7	70	57	46.7	71.4	64	20
96	85	33.3	66	60	45	30	68	52	40	65.7	58	20
104	85	33.3	58	56	45	30	60	48	40	61.4	55	20
112	85	33.3	56	55	45	30	54	45	33.3	57.1	50	13.3
120	85	33.3	52	53	45	23.3	50	41	30	51.4	45	6.7
128	85	30	48	50	45	23.3	46	39	30	50	44	6.7
136	80	26.7	46	47	40	16.7	38	32	26.7	41.4	37	0
144	75	26.7	44	45	40	16.7	38	32	23.3	38.5	34	
152	75	26.7	42	44	35	13.3	34	28	23.3	38.5	34	
160	75	23.3	34	39	35	10	30	23	20	34.2	30	
168	75	20	28	35	35	10	26	23	16.7	32.8	28	

Direct contact of the insects with the poisoned mixtures seemed to increase considerably the toxicity of the two compounds, and especially that of sodium fluoride.

Out of 165 insects tested with thiodiphenylamine at concentrations of

from 4 to 20 per cent, only six were killed in seven days, and these at the highest concentration. Direct contact with this poison apparently did not increase its toxicity.

Discussion.—It will be noted from a study of the graph that all concentrations of sodium fluoride killed faster than arsenic trioxide and that the former killed 90 per cent or more of the insects while the latter killed from 65 to 77 per cent, in seven days. Thus, sodium fluoride under these conditions was the more effective poison. The graph also shows that in the highest concentrations both poisons killed slightly fewer insects than the next lower concentrations. This may be attributed to a slight repellent effect at the higher concentrations. From the above it may be assumed that the lower percentages used are just as effective as the highest concentrations over a period of seven days or more.

Practical recommendations.—The arsenical bait formulated by Wakeland & Waters has been tried at Iowa State College in infested buildings and found effective. The present study has shown, however, in parallel experiments in vials, that the same food with sodium fluoride is at least equally and more quickly effective. Moreover, since the fluoride is a somewhat safer poison to use in houses, a modification of the Wakeland & Waters recipe is recommended in which sodium fluoride is substituted for arsenic trioxide. This mixture has likewise been tested in two infested houses and found very effective. The recipe is:

Rolled oats (finely ground).....	86 parts by weight
Powdered sugar (icing sugar).....	5 parts by weight
Common salt (powdered).....	2 parts by weight
Sodium fluoride.....	7 parts by weight
	100

All the ingredients must be ground to floury or powdery consistency, thoroughly mixed and then reground. A hand mill may be used. The use of water to incorporate the sugar, salt and poison into the oat flour, as advocated by Wakeland & Waters, is regarded as unnecessary.

Four hundred fifty grams, or about one pound, of this mixture is enough to treat an ordinary dwelling house several times.

This poisoned food should be scattered thinly in the bottoms of shallow cardboard boxes and covered by a sheet of crimped paper somewhat narrower than the box, The boxes may be set on the floor, under furniture, on shelves, in corners and in basements near heating fixtures, or wherever the insects are likely to find them. Firebrats seem to find their food largely by direct antennal contact. The bait will be most effective in the warmest part of the house. The mixture should be scattered loosely only with caution and should be swept up after it becomes no longer useful.

The destruction of firebrats by means of baits is not likely to be complete and since there is likelihood of reinfestation it is advisable to leave some of the bait exposed long after the last firebrats are seen, or to renew it whenever they reappear.

Such a poisoned bait is recommended for use only where the firebrats have evinced hunger by attacking paper glaze, woolens or similar starva-

tion foods. Preliminary tests were run in which firebrats, in two groups of forty-three individuals, had access to measured quantities of the bait, without poison, with 8 per cent arsenic trioxide, and with 8 per cent sodium fluoride. The insects ate over ten times more of the unpoisoned bait than of either of the poisoned baits. For this reason the use of poisoned bait is not recommended in places such as bakeries where the insects usually have access to plenty of preferred food.

Summary.—Firebrats reared and kept at 34.5° C and about 70 per cent relative humidity were confined singly with access to their preferred food mixed with various concentrations of three poisons. Care was taken that the insects were not compelled to remain in contact with the bait. In addition to the controls, none of which died, 100 individuals were tested with each concentration for periods of one week.

With thiodiphenylamine, at concentrations up to 20 per cent, only a few insects died in one week. With arsenic trioxide, 4, 12 and 20 per cent, about two-thirds of the insects died. With sodium fluoride, 4, 8 and 12 per cent, about nine-tenths of the insects died.

Preliminary tests indicated that both contact effects and repellence by poisons are significant in the effectiveness of these mixtures.

A bait is recommended in which 7 per cent of the weight is sodium fluoride.

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TOXIC ACTION OF FORMALDEHYDE ON THE ADULT HOUSE FLY[1]

MUSCA DOMESTICA L.

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Formaldehyde, when pure, occurs as a gas and is fairly stable at temperatures below −30° C, but it can be kept only a few hours without polymerization. Even the smallest trace of water will cause this change. Commercial formaldehyde consists of formaldehyde vapor dissolved in water to a concentration of 37 to 40 per cent formaldehyde with small amounts of methyl alcohol and traces of formic acid as impurities. In aqueous solution an equilibrium exists between the unimolecular and polymolecular states, the degree of polymerization varying with the temperature and concentration. Certain impurities may increase polymerization rapidly.

[1] From a thesis presented to the graduate school of Iowa State College, Ames, by the senior author in partial fulfillment of the requirements for the Master of Science degree.

Since 1903 when C. H. Popenoe (*6*) accidently discovered its effectiveness as a stomach poison for house flies, the efficiency of formaldehyde as an insecticide has been the subject of considerable speculation. This speculation has arisen from the wide variability in effectiveness of supposedly equivalent amounts of formaldehyde in house-fly baits.

Lloyd (*7*), in attempting to determine the reasons for the variability of these house-fly baits found that the commercial formaldehyde in common use at that time contained other chemicals in varying amounts. After obtaining data from a number of experiments in which the repellent effect of these impurities, especially that of formic acid, was demonstrated he concluded that the neutralization of the formic acid in commercial formaldehyde might decrease this repellence. Saturated lime water, .14 per cent $Ca(OH)_2$, was found to be the best alkali for this purpose. Lloyd obtained an increase in the percentage of mortality by neutralizing commercial formaldehyde in this way. He based his conclusions largely on the number of dead flies surrounding bait dishes exposed in a fly room.

Morrill (*8*) commented on the poor results obtained from formaldehyde in sugar or milk solutions and showed that baits containing beer, ethyl alcohol or vinegar with formaldehyde were more attractive.

The present investigation was undertaken, first, to determine the reasons for the variable effects of formaldehyde on the house fly; second, to observe its physiological effects; third, to determine the median lethal dose for the house fly; and fourth, to compare milk with sugar as a bait.

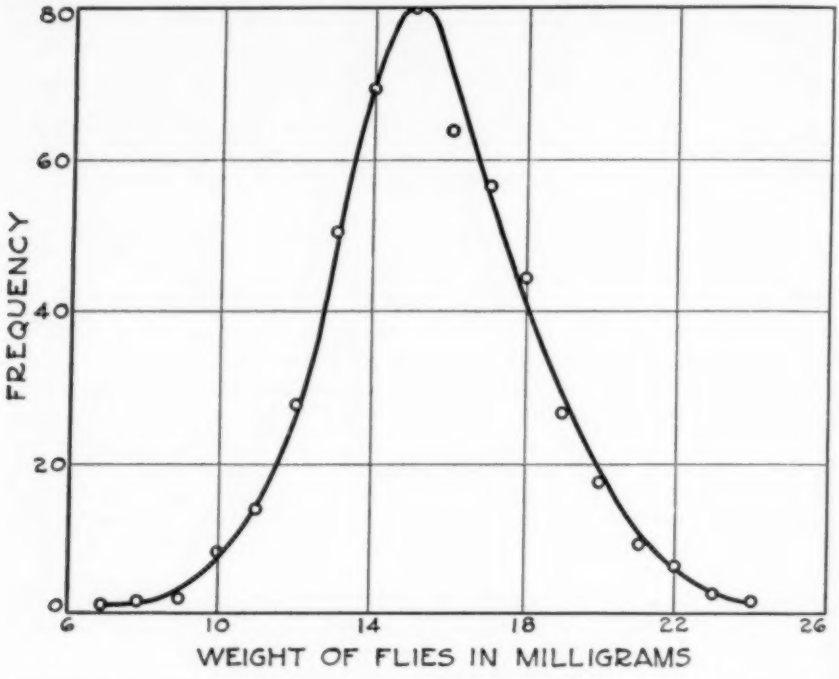
Materials.—The flies used in this study were reared and handled according to the method used by Pearson (*9*), which is a modification of that previously described by H. H. Richardson (*10*). The flies were reared in a breeding room at a temperature ranging from 29 to 33° C. Unfed flies, 12 to 20 hours old, were used in all tests. Preliminary experiments indicated that toxic doses of formaldehyde were not taken by flies less than 12 hours old.

In order to obtain data which would represent house flies in general, the insects were taken at random, a few each day from October to May, from the entire population reared under the conditions as indicated. The weights of 490 flies so chosen were tabulated in order to present a graphic picture of the weight of the individuals in the populations from which the experimental insects were drawn, fig. 1. The mean weight of the individual flies was $15.6 \pm .1$ milligrams with a range of 7 to 24 milligrams. The standard deviation (2.7) and the corresponding probable error (1.8) are sufficiently small to bring a large proportion of the population within rather narrow limits. The median (14.8) indicates a slightly skewed distribution.

The commercial formaldehyde used in these experiments contained 37 per cent formaldehyde (HCHO), .2 per cent formic acid and 15 per cent methyl alcohol. For certain tests, this formaldehyde was neutralized before use with standard potassium hydroxide solution, purified litmus being the indicator. The addition of any alkali such as potassium hydroxide or calcium hydroxide (lime water), besides neutralizing the formic acid, causes an increase in polymerization (*3*). Therefore, neutralized

formaldehyde solutions contain a proportionately smaller amount of unimolecular and a larger amount of polymolecular formaldehyde than solutions of the ordinary commercial product.

The paraformaldehyde,[2] a chemically pure product, was dissolved by boiling the soilid in distilled water. According to Auerbach & Barschall (*2*) this solution contains a certain amount of unimolecular as well as polymolecular formaldehyde, with the latter probably predominating as in the neutralized solutions of commercial formaldehyde.



The concentration of formaldehyde in all solutions was determined as HCHO by the official hydrogen peroxide method (*1*).

Sugar (sucrose) was used in the formaldehyde solutions to make them more attractive to the flies; the solutions contained 15 grams of lump sugar per 100 cc.

Three types of media were used. One contained 80 per cent pasteurized, sweet, skimmed milk, another 50 per cent skimmed milk and 15 per cent sugar, and a third 15 per cent sugar.

Methods.—Unfed flies were transferred directly from the cages to tared weighing bottles. They were weighed singly before and after feeding and the amount of solution imbibed was determined by difference. The method of feeding was that used by Pearson (*9*) in which a measured

[2] Paraformaldehyde $(CH_2O)nH_2O$, was used in these experiments. It is often referred to in the literature as trioxymethylene. True alpha trioxymethylene $(CH_2O)_3$, is not commercially available at the present time.

drop of solution was delivered by a micropipette to a clean glass plate. The inverted weighing bottle served as a feeding cage.

After the flies had been fed and weighed they were placed individually in cages and supplied with sugar solution. Several groups were observed for four days following treatment but no mortality occurred after the first day. Since a large percentage of the flies affected by the formaldehyde were anesthetized in the first few minutes after feeding, the exact time of feeding and the time from feeding to complete anesthesia were recorded. Most of this work was done in the evening, making it necessary to record the mortality, which occurred during the night, on the followlowing morning. The toxicity of formaldehyde, in terms of the time required to kill, was somewhat obscured by this anesthetic effect which preceded death. Flies recovering from anesthesia were distinguished in the records from those which succumbed.

The repellent effect of various solutions was determined by offering each fly an excess of solution on the glass plate used in the other tests. After determining the weight of each fly together with the weight of solution imbibed, the amount of formaldehyde which each fly received before it left the solution was easily calculated.

Symptoms produced.—Formaldehyde causes a progressive paralysis of the nervous system of the house fly in an anterior direction, beginning with the tip of the abdomen and reaching finally the mouth parts and the antennae. A rather definite chain of events which were recorded by observing poisoned flies under the microscope agree in general with Hiestand's (*5*) description of these phenomena.

Determination of the median lethal dose.—The median lethal dose is usually not difficult to determine with nonrepellent stomach poisons, of which many lethal as well as sublethal doses may be administered to indicate the limits of an intermediate zone (*4*). Formaldehyde, however, is difficult to administer to house flies in lethal doses because imbibition of the necessarily rather large quantity of liquid is often followed by regurgitation.

The following four solutions containing formaldehyde were used to determine the median lethal dose (M.L.D.): (1) 80 per cent milk solution without sugar but with unneutralized commercial formaldehyde, (2) 80 per cent milk solution without sugar containing paraformaldehyde, (3) milk and water, equal parts, 15 per cent sugar and paraformaldehyde, (4) a 15 per cent distilled-water solution of sugar containing paraformaldehyde. From 1 to 4 per cent of formaldehyde or of paraformaldehyde (determined as HCHO) was added to each solution. The first solution was fed successfully to 42 flies, the second to 59 flies, the third to 51 flies, and the fourth to 78 flies. All of the doses of paraformaldehyde administered in the media described above were found to be sufficiently alike to be grouped together in the second subdivision of table 1. The method of analysis of variance (*11*) was used to test for homogeneity in this series. When doses of formaldehyde (expressed as HCHO) from unneutralized commercial formaldehyde, table 1, were compared with the doses of paraformaldehyde referred to above, they were found to be significantly different. The M.L.D. of paraformaldehyde (as HCHO) is estimated at

2.24 milligrams per gram of body weight, whereas that of formaldehyde (as HCHO) from the commercial product (unneutralized) is estimated at 1.54 mg./g. The M.L.D. of 1.54 mg./g. for HCHO from commercial formaldehyde may be significantly lower because only the smaller doses were accepted by the flies. The toxicity data are given in table 1.

Nineteen of the flies included in the alive column under paraformaldehyde solutions were anesthetized but recovered later, as also did three of the flies included in the alive column under commercial formaldehyde. These 22 flies imbibed doses of poison calculated as HCHO ranging from .2 to 4.8 mg./g., the mean dosage being 1.53 mg./g., or somewhat less than the M.L.D. of paraformaldehyde calculated as HCHO. In addition, 20 flies, which regurgitated soon after feeding, imbibed larger doses which however were lost before they could be determined.

Table 1.—Toxicity of formaldehyde to the adult house fly.

Dose in Milligrams	Paraformaldehyde Solutions[3]			Commercial Formaldehyde in 80 Per Cent Milk Solution		
	Sublethal Zone	Intermediate Zone[4]		Sublethal Zone	Intermediate Zone	
		Alive	*Dead*		*Alive*	*Dead*
.01– .5	27			6		
.51–1		25	13		9	2
1.01–1.5		16	6		5	3
1.51–2		20	8		9	1
2.01–2.5		16	11		2	2
2.51–3		15	1		1	1
3.01–3.5		6	2		1	
3.51–4		4	5			
4.01–4.5		2	1			
4.51–5		3	2			
5.01–5.5		0	1			
5.51–6		2	2			
Mean		2.28	3.22		1.54	1.54
Median lethal dose (as HCHO)			2.24			1.54

When the time required for death in the 62 cases (the dead columns for paraformaldehyde and commercial formaldehyde solutions) was compared with the doses, there was no relation between the size of the dose and the survival time. Seventy-three per cent of the 62 flies were anesthetized in the first five minutes after feeding and did not recover. After 12 hours the remaining 27 per cent were considered dead. There was no significant difference between the mean dosage of those anesthetized in a few minutes and those which died in 12 hours.

Repellence.—The degree of repellence of a number of solutions containing formaldehyde was measured by calculating the weight of solution in milligrams imbibed per gram of body weight by flies which were allowed to feed *ad libitum*. As a means of comparing the acidity of the various solutions, the pH value of each has been determined. The results are given in table 2.

An analysis of the data reveals some interesting relations. The amounts of milk solution and of sugar solution without formaldehyde imbibed by the control flies varied from 250 to 953 mg./g., the mean amounts of

[3] The solutions contained 80 per cent milk, 50 per cent milk and 15 per cent sugar or 15 per cent sugar in distilled water.

[4] Due to repellence it was not possible to obtain cases in the lethal zone.

each solution being substantially larger than those of the solutions which contained toxic ingredients.

Sugar, however, appears to be a better bait than milk. It may be assumed that a difference really exists when it is noted that the mean and maximum dosages are larger for the sugar solution than for the milk solution.

A 3 per cent formaldehyde solution, obtained by diluting 37 per cent commercial formalin without previous neutralization, appeared to be rather repellent in both milk and sugar solutions. This repellence, represented by the means of 51 and 73 mg./g. respectively, does not seem

Table 2.—Relative repellence of various formaldehyde solutions to the adult house fly.

Solutions	No. Flies Tested	pH of Solution	Amount of Solution Imbibed in Milligrams Per Gram of Body Weight		
			Minimum	Mean	Maximum
Sugar solution (15 gm. sugar in 100 cc.) without HCHO	16	5.3	250	584	953
Milk solution (80% milk) and sugar without HCHO	13	6.2	260	519	807
Sugar solution with 3% paraformaldehyde as HCHO; pH adjusted with formic acid	10	3.5	36	156	329
Sugar solution with .2% formic acid	10	2.4	17	154	248
Sugar solution with neutralized commercial formaldehyde (3% HCHO)	10	5.3	16	112	309
Equal parts milk and sugar solution with 2.25–3% paraformaldehyde as HCHO	37	5.7	10	102	255
Sugar solution with 2.6–3.4% paraformaldehyde (as HCHO)	40	4.4	12	94	270
Milk solution (80% milk) with 2.6–3.4% paraformaldehyde (as HCHO)	41	5.7	11	89	246
Sugar solution with commercial formaldehyde unneutralized (3% HCHO)	12	3.5	8	73	128
Milk solution (80% milk) without sugar but with commercial formaldehyde unneutralized (3% HCHO)	26	5.9	11	51	87

to result entirely from the presence of formic acid in the solutions. Formic acid in sugar solution and in paraformaldehyde—sugar solution, represented by mean values of 154 and 156 mg./g., was much less repellent than commercial formaldehyde; this, in spite of the low pH values of 2.4 and 3.5 respectively. The pH of the paraformaldehyde—sugar solution was adjusted to equal that of the commercial formaldehyde solution.

Methyl alcohol was present in the commercial formaldehyde solution at a concentration of about 15 per cent; its highest concentration in the solutions fed to the flies was about 1.6 per cent. Preliminary tests with methyl alcohol in sugar solution showed that as much as 4 per cent of methyl alcohol was neither repellent nor toxic within 24 hours to house flies.

Discussion.—That formaldehyde causes progressive paralysis of the nervous system of the house fly in an anterior direction seems to be well established. The imbibition of sublethal doses may be followed by a reversible action and recovery.

There appears to be no difference in the median lethal dose of formaldehyde whether it is administered in a sugar or a milk solution. Formaldehyde undoubtedly reacts with the casein and lactose of milk and with sucrose to form condensation products but the degree of reaction is not definitely known. W. O. Walker (*13*) has shown that when formaldehyde is added to milk the neutral character of casein disappears with the result that the acidic property predominates. The quantity of casein present may be determined by the amount of alkali required to neutralize these acidic groups. The reaction of formaldehyde with both sugar and milk is a possible source of error which has not been eliminated in this brief study.

The exact cause of repellence has been definitely shown not to be due to formic acid. Since the paraformaldehyde solution and the neutralized commercial formaldehyde solutions were both less repellent than the unneutralized commercial formaldehyde solutions, it seems logical to explain the difference by the degree of polymerization of the formaldehyde. F. Walker (*12*) discusses formaldehyde at length and emphasizes its tendency to polymerize readily. The polymerization of formaldehyde by calcium hydroxide to form a mixture of hexoses containing alpha acrose is well known (*3*).

The median lethal dose of 2.24 mg./g. of formaldehyde refers only to formaldehyde calculated as HCHO when contained in the solutions described.

Summary and conclusions.—The effect of formaldehyde on the adult house fly *Musca domestica* L. was determined by feeding individual flies small drops of solutions which contained known concentrations of formaldehyde or paraformaldehyde. The amount of toxic liquid imbibed was ascertained immediately after feeding from the gain in weight of the fly. The population from which the test insects were taken comprised flies weighing from 7 to 24 milligrams with a mean weight of 15.6 $\pm$ .1 milligrams.

Formaldehyde causes a progressive paralysis of the nervous system from posterior to anterior. The median lethal dose of paraformaldehyde calculated as HCHO is estimated as 2.24 mg. per gram of body weight; for commercial formaldehyde it is estimated as 1.54 mg. HCHO/g. The greater toxicity of unneutralized commercial formaldehyde solutions as compared with paraformaldehyde solutions probably results from the greater concentration of unpolymerized formaldehyde in the former solutions. The greater repellence of the commercial formaldehyde solutions may also contribute to their lower M.L.D.

Formic acid solution (pH 2.4) was less repellent to house flies than a 3 per cent solution of unneutralized commercial formaldehyde of pH 3.5. Paraformaldehyde solution (3 per cent HCHO) adjusted to pH 3.5 with formic acid was also less repellent than unneutralized commercial formaldehyde solution. A solution of commercial formaldehyde, neutralized with potassium hydroxide, was similar in repellent properties to paraformaldehyde solution of equivalent HCHO concentration. The addition of alkali to commercial formaldehyde solution causes rapid polymerization was well as acid neutralization. The greater repellence of unneutral-

ized commercial formaldehyde solution is probably the result of the greater concentration of unpolymerized HCHO in such solutions.

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MECHANISM OF ABSORPTION OF PYRETHRUM POWDER BY ROACHES

George L. Hockenyos, *Springfield, Ill.*[1]

There are four common ways of using pyrethrum—as a powder, as an oil extract, as a water solution and as suspension or emulsion of an extract. There has been a great deal of study applied to the problem of securing penetration of the tracheal system by means of water solutions, suspensions and emulsions of pyrethrum, as well as of many other contact poisons. It can be demonstrated that oils and oil extracts penetrate the trachea, but there seem to be no data dealing with the specific means whereby the toxic principles of pyrethrum powder enters the insect body when the pyrethrum is used as a powder.

In some preliminary tests it was found that if a roach is heavily dusted with pyrethrum powder it evidences no reaction for a period of about one and a half minutes; than a sudden and intense excitement takes place.

[1] Contribution from the entomological laboratories of the University of Illinois.

The insect rushes wildly about for approximately two minutes more, when evidences of paralysis are noted. This usually begins with the metathoracic legs and spreads to the other legs. In about eight minutes from the time of applying the dust, the insect is on its back and helpless. During the period of excitement the roaches usually wash the antennae in frantic haste.

Table 1.

Powder	Inception of Excitement Minutes	Inception of Paralysis Minutes	Helplessly Paralyzed Minutes
Pure pyrethrum powder, 80-mesh talc			
No. 1	1½	4	7
No. 2	1½	3	6
No. 3	1⅓	3	8
No. 4	1¼	3½	5
No. 5	1⅓	3	8
Average	*1.4*	*3.1*	*6.8*
Pyrethrum powder 50%, 300-mesh talc 50%			
No. 1	2	7	12
No. 2	2	7	12
No. 3	1¾	8	9
No. 4	2	9	10
No. 5	1¾	9	11
Average	*1.9*	*8*	*10.8*
Pyrethrum powder 25%, 300-mesh talc 75%			
No. 1	1	5	6
No. 2	¾	7½	10
No. 3	1½	4	6
No. 4	3	6	8½
No. 5	1¼	9½	13
Average	*1.5*	*6.4*	*8.7*
Pyrethrum powder 10%, 300-mesh talc 90%			
No. 1	1¾	25	60
No. 2	1¾	11	15
No. 3	1¾	11	15
No. 4	1½	21	22
No. 5	1¾	18	21
Average	*1.7*	*17.2*	*18.2* (*Ave. of four*)

Table 1 gives data obtained by taking Oriental roaches individually, dusting them heavily with the powder indicated, placing them in separate observation jars, and timing their reactions.

The data in table 1 were supplemented by a test wherein 5 per cent pyrethrum and 95 per cent talc was used. In this case the reaction of the insects was erratic in that the excitement was not continuous nor so intense as in all the other tests. The only definite data was the time elapsing before each insect was helpless. The periods of time for the five were respectively, 14, 15, 18, 25 and 28 minutes, or an average time of 20

minutes. A test using 15 per cent pyrethrum and 85 per cent talc rendered the five roaches helpless in the following time intervals: 8, 7, 9, 11 and 13 minutes, or an average of 9.6 minutes.

All of the above specimens were kept for observation of their recovery. Table 2 gives the time elapsing between treatment and observation and the condition of the insects observed.

Examination of tables 1 and 2 shows that where concentrations of 10 per cent or more of pyrethrum were used in the dust there was a definite period of induction before any reaction was observed. This period averaged 1.6 minutes for all tests observed, and there was but little deviation from this average in the various tests. Both the time elapsing before paralysis set in and again before the insect was helpless varied inversely with the concentration of pyrethrum. There is evidence in these tables that 25 per cent pyrethrum is more efficient than either

Table 2.

Material	Time Elapsing Hours	Condition
Pure pyrethrum	11½	1 dead, 4 helpless
Pyrethrum 50%	10½	4 helpless, 1 practically normal
Pyrethrum 25%	10	1 dead, 2 helpless, 2 partly recovered
Pyrethrum 15%	9	1 nearly dead, 2 helpless, 2 recovered
Pyrethrum 10%	9½	4 helpless, 1 recovered
Pyrethrum 5%	9	1 dead, 4 recovered

50 per cent or any concentration less than 25 per cent. This evidence is substantiated by the experience of a commercial entomologist who reported to the writer in a personal communication that he found that increasing the amount of pyrethrum in an insect powder above 25 per cent did not speed up its action until a concentration of more than 50 per cent was reached. Hockenyos, in Crop Protection Bulletin **31**, p. 25, presents a table where 50 per cent monochlornapthalene is shown to be more effective than either 25 per cent or 100 per cent as a house-fly spray, the diluent being kerosene. Hockenyos & Lilly, in the JOURNAL **25** (2):253–60, April 1932, present graphs showing that various poisons when injected hypodermically in large larvae have concentrations of maximum effectiveness, and both above and below these concentrations effectiveness is diminished.

In the first paper of this series, a technique was described whereby a powder could be applied to any desired part of an individual roach. This technique was used to test the ability of the toxic principle of pyrethrum powder to penetrate the body integument of the roach.

In the first test, five roaches were placed in straitjackets with their heads free. Finely powdered pyrethrum was then applied to the junction of the head and thorax with a camel's-hair brush. Twelve hours later the roaches were released and found to be practically normal, save that the antennae were paralyzed and quite useless to the insects.

In another test five roaches were dusted heavily on the ventral side of the thoracic segments and then released in a jar for observation. In about five minutes they were removed to a second jar and it was noted that the usual periods of excitement and the partial paralysis occurred,

but that the insects did not become helpless and in 12 hours were normal save for a rather stilted gait in walking.

Five other roaches were similarly dusted but the excess dust immediately blown off with an air jet. They showed less reaction than those from which the excess dust was not removed and were entirely normal in 12 hours.

The powder was also applied to the entire abdominal surface of five roaches, using care not to allow any to get on the thorax. These insects were placed in separate jars and all passed through the usual cycle of excitement and paralysis. In 12 hours they were all quite helpless.

In the three foregoing experiments, the pyrethrum may or may not have entered the spiracles, since either the thoracic or abdominal spiracles were treated and the other left untreated, thus making it possible for the insect to close the set which had been dusted and use only the undusted set.

To determine this point, pyrethrum powder was applied with a camel's hair brush to all of the spiracles, using as little excess as possible beyond that required to cover the spiracles well. These roaches showed excitement and slight paralysis but were practically normal in 12 hours.

The above tests were supplemented by a slightly different technique whereby the roaches were partially imbedded in paraffin placed on top of cork stoppers. In this way they were held inverted and pyrethrum applied to the ventral surface of the thorax without dropping off. With the roaches held in this manner, all of the above experiments were repeated with identical results.

It had been found that either the abdominal half or the cephalothoracic half of a roach could be dipped in medium hard paraffin which had been heated to the point of being just completely fluid without injury to the insect if it were promptly dipped in cold water to chill the paraffin.

Five roaches were now dipped repeatedly in paraffin until a large deposit was formed over the entire abdomen. Pyrethrum powder was now applied to the region of the thoracic spiracles, and the insects were laid in an inverted position. In 12 hours, their efforts to crawl seemed normal.

Five roaches similarly dipped but dusted heavily over the entire head and thorax were nearly dead in 12 hours. Five other roaches whose heads and thoraxes had been dipped in paraffin were dusted heavily over the entire abdomen with pyrethrum; three were found to be dead in 12 hours while the other two were nearly so.

To test the ability of paraffin to exclude air from the body region which had been dipped, the following test was carried out. Individual roaches were seized just back of the head with a small pair of thin-bladed crucible tongs. The entire abdomen and thorax were dipped in paraffin and then cold water. Fifteen roaches were so treated, each being dipped two or three times to insure a heavy deposit. Since the head and antennae were not dipped, it was possible to obtain evidence of life by the motion of the antennae. Ten of the 15 treated roaches died very promptly, but five were alive at the end of two hours. These were found to have cracked the paraffin along the lateral edges of the abdomen and were breathing

by means of a dorso-ventral expanding movement. It seems reasonably safe to believe that paraffin, if applied heavily to either the abdomen or thorax as it was in some of the above described experiments, can be depended upon to force respiration to take place exclusively through the uncoated body region.

All of the above described experiments indicate that pyrethrum does not affect roaches by entering the trachea, but rather is absorbed directly through the body integument; and, further, that with the particular sample of pyrethrum used an area of one half or more of the body region must be covered with the dust to insure the insect's being paralyzed for at least 12 hours.

Finally, two tests were made to determine the importance of ingestion as a mode of absorbing pyrethrum powder. Pyrethrum powder was brushed thoroughly onto the antennae of five roaches. They evinced great discomfort and washed the antennae repeatedly by drawing them through the mouth parts. After all had finished the washing process, they weregiven a second and similar dust application. The washing process was seen to be repeated, but the roaches were apparently not affected for 12 hours, other than by a show of discomfort.

A similar experiment was conducted except that the pyrethrum powder was applied to all six legs. Only one application was made and the roaches were not seen to be affected, though they were observed to wash the powder from the legs in the same manner as they had from the antennae.

Conclusions.—When pyrethrum powder is applied to roaches there is a period of induction before any reaction is evinced. This period approximates one and a half minutes and does not vary for any concentration of powder that is strong enough to induce the reaction. This first reaction is one of great excitement and is followed by a stage of partial paralysis and then helpless paralysis. The time elapsing before the incidence of these last two reactions is influenced inversely by the concentration of pyrethrum in the dust being used.

There is evidence that a dust containing 25 per cent pyrethrum powder is more effective than one containing 50 per cent pyrethrum or one containing less than 25 per cent, but less effective than one containing 100 per cent.

A roach dusted with pyrethrum powder is probably most affected by the absorption of the toxic principles directly through the body integument, and very little by either penetration of the spiracles or ingestion through the mouthparts.

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TANK-MIXTURE METHOD OF USING OIL SPRAYS FOR DECIDUOUS FRUITS

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Success of the tank-mixture method of using oil sprays for the control of citrus insects in southern California (*2*) prompted an investigation of its use in the spraying of deciduous fruits in northern California. The results of investigations made in the laboratory and in the field during the past three years show that it is more efficient and economical than proprietary emulsions in the control of many insect pests on deciduous fruit trees.

Studies on the oil-depositing properties of oil emulsions and summer-oil emulsions showed that there was a very wide variation in the amount of oil deposited by different brands. With the dormant emulsions the oil deposit on 25 square inches of waxed surface, sprayed for 15 seconds with a mixture of 5 per cent actual oil, ranged from 22 to 55 mg. With the summer-oil emulsions the deposit on the same area with the same exposure and a 1 per cent concentration gave deposits ranging from 4 to 28 mg. This wide variation in deposit is undoubtedly due to differences in the kind and amount of emulsifier used in the various emulsions. Since insecticide manufacturers have given but little consideration to oil-depositing property and have generally recommended the use of a given dosage for all products, much variation in control has been experienced. With the dormant oil emulsions the same dosage is recommended for the emulsion giving a deposit of 55 mg. as for the one giving a deposit of only 22 mg. When a change is made in the formula of an emulsion, as is frequently done, the oil deposit may be increased or it may be decreased.

Investigation has shown that undesirable blends of oils, as regards both volatility and unsulfonated residue, have been used in some proprietary emulsions. Such blends do not give as high an efficiency in control and may under certain conditions produce injury.

In the tank-mixture method the spreader and oil are added to the water in the spray tank and a uniform mixture is maintained by effective agitation. We have found that four ounces of powdered blood albumen spreader to 100 gallons of dilute spray gives a higher oil deposit than any of the proprietary oil emulsions and that this spreader may be safely used under "hard water" conditions. The spreader consists of 1 part grade A powdered blood albumen (*2*) and 3 parts finely ground earth. It is prepared by manufacturers and is put up in two convenient sizes in glassine-lined packages; an 8-ounce package sufficient for a 200-gallon tank and a 12-ounce package sufficient for a 300-gallon tank.

As a result of field investigations we have recommended for dormant sprays a "straight-cut" spray oil having a viscosity of 100–120 seconds Saybolt at 100° F and an unsulfonated residue not lower than 70 per cent. This oil is designated as grade A tank-mix oil. For summer tank-mix sprays we use grades 1, 2 or 3 having viscosities ranging from 50 to

70 seconds Saybolt and unsulfonated residues not lower than 90 per cent as standardized for citrus spraying (*2*).

Uniform mixture of the oil and water in the modern spray tank is not difficult or expensive to obtain. At the relatively low speeds of the agitator shaft on most spray outfits the propeller-type blades will *not* give adequate agitation. Uniform mixtures may be obtained with the propeller-type agitators by speeding the agitator shaft up to 200 rpm. (*2*) or by using the new flat-type agitators (*1*) and running the shaft at around 100 rpm. The energy consumption for agitation alone at the higher speed is around one-half hp., which is negligible for outfits with 8-hp. motors or above, and at the lower speed it is one-fourth hp., which is more practical with the low-powered outfits generally used in deciduous fruit districts.

Our results in control of the major insects on deciduous fruits have been very satisfactory. In fact, it has been possible to use the oil in tank-mix spray at a much lower dosage than proprietary emulsions and yet obtain excellent results.

The advantages of the tank-mixture method over the use of the commercial oil emulsions may be briefly summarized as follows:

1.—In a tank-mixture spray a "straight-cut" oil of definite known specifications is employed with a spreader of definite, known depositing and spreading properties.

2.—The oil-depositing properties of the spray are higher than those found in any commercial emulsions, permitting the use of lower concentrations.

3.—In a tank-mixture spray there is a very satisfactory oil film deposited on the bark with less run-off than occurs in most proprietary emulsions.

4.—Due to the higher oil deposit and uniform oil film in the tank-mixture method the dosage required is less than that for commercial emulsions.

5.—The spreader used in the tank-mixture method is not affected by hard water and permits combinations with lime sulfur, Bordeaux mixture and caustic soda without breaking the emulsions.

6.—The cost of material for tank-mix spray is approximately fifty per cent less than the cost of commercial emulsion, on the basis of present prices.

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OBSERVATIONS ON THE WEST INDIAN FRUIT FLY AT KEY WEST IN 1932–33

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The West Indian fruit fly *Anastrepha acidusa* Walk. and *Anastrepha suspensa* Loew,[2] which are referred to in this paper under one common name, was discovered on the Island of Key West, Fla., in November 1930,[3] and in November 1932, the Bureau of Entomology, in cooperation with the State Plant Board of Florida, began certain investigations of the two species. At the outset it was anticipated that the insects would be completely eradicated in due time from the Island of Key West, the only place in Florida where intensive inspection had disclosed their presence, and these studies were undertaken to furnish information needed to assist in the campaign. In July 1933 a program of eradication was outlined and highly satisfactory progress in cleaning up host fruits and in spraying had been made.

Habits of the adults.—The habits of the adults of the species *A. acidusa* and *A. suspensa* were studied under cage conditions in the insectary. Under these conditions the flies of both species, in general, exhibited approximately the same characteristics as regards mating, pre-oviposition period and oviposition.

Mating.—The flies were not sexually mature when they emerged. The time from emergence to mating varied with the season and apparently with the temperature. The time required by females of the species *A. acidusa* to reach sexual maturity, as determined by first matings, ranged from 14 to 17 days after emergence in November 1932, and January, February and March, 1933; and from 12 days in April to seven days in July 1933. The time required by females of the species *A. suspensa* to reach sexual maturity, as determined by first matings, ranged from 20 days after emergence in February to nine days in May 1933.

Mating occurred in the cages at all hours of the day, but more frequently between the hours of 10 a.m. and 3 p.m. Pairs mated at intervals throughout their lives.

Oviposition began shortly after mating, usually within one to three days. Fertilization of the female, however, was not required to initiate oviposition, as several females were observed to go through the oviposition process prior to mating, but without laying fertile eggs. In no case were unmated females observed to lay viable eggs.

Pre-oviposition period.—Length of the pre-oviposition period also varied with the season and apparently with temperature. The length of the pre-oviposition period of females of the species *A. acidusa* ranged from 16 to 20 days (average 16.9 days) during the period November 1932 to March 1933, and from eight to 13 days (average 9.1 days) during

[1] In cooperation with the State Plant Board of Florida, whose personnel stationed at Key West rendered valuable assistance during the entire period of the investigations.

[2] Identifications by C. T. Greene.

[3] State Plant Board of Florida, 9th Bienn. Rep., pp. 17–20 (for the period July 1, 1930, to June 30, 1932).

the period April to July 1933. The length of the pre-oviposition period of females of the species *A. suspensa* was observed to be 21 days in February and 10 days in May 1933.

OVIPOSITION.—The oviposition experiments to determine the fruits which the West Indian fruit fly would attack were conducted in wooden cages, approximately 8 by 10 by 10 inches, covered with cheesecloth on two sides and top, and with glass in front and back. Each cage contained about 25 male and 25 female flies. The flies were fed sliced orange every morning. Each day fruit was introduced into the cages and left for 24 hours. Guavas, and, when available, Barbados cherries and Surinam cherries, were always included in each cage. Thus one of the presumably more preferred host fruits was always present in the cages, and the flies were free to oviposit in the preferred fruits or in the test fruits. By the use of this method the flies were not forced to oviposit in any one fruit. These studies have shown that the flies of the species *A. acidusa* may successfully attack 35 kinds of fruit; that is, the flies successfully oviposited and the resulting larvae subsequently developed in 35 kinds of fruit. The flies of the species *A. suspensa* successfully attacked many of the same fruits under cage conditions. The principal difference noted between the two species of flies in the oviposition experiments was that the flies of the species *A. suspensa* preferred guavas and the flies of the species *A. acidusa* preferred *Spondias* sp. The fruits that were successfully attacked in the oviposition experiments are listed in table 1. Under field conditions at Key West, Fla., the flies of the species *A. acidusa* were reared from hog plums, *Spondias mombin*, and guavas, while flies of the species *A. suspensa* were reared from guavas only.

LONGEVITY.—The determinations of longevity were made by confining male and female flies in small cages, similar to those used in oviposition experiments, and providing sliced orange and water for feeding. The duration of life of 23 female and 22 male flies of the species *A. acidusa* which emerged on November 27, 1932, averaged 78.6 days; the minimum longevity was six days and the maximum length of life of 147 days was attained by two female flies of the group. The duration of life of 27 female and 21 male flies of the species *A. acidusa* which emerged on April 4, 1933, averaged 101.3 days; the minimum longevity in this group was eight days and the maximum length of life of 188 days was attained by one male fly. A female fly in this series lived to be 169 days old. Twelve flies without food or water survived for an average of 8.3 days.

The duration of life of eight female and eight male flies of the species *A. suspensa* which emerged on December 3, 1932, averaged 50.2 days; the minimum length of life was nine days and the maximum longevity was that of a male fly which lived 145 days. Two female flies of the species *A. suspensa* which emerged on February 27, 1933, from field-collected guavas, lived 62 and 72 days, respectively.

Insecticide tests.—In anticipation of the beginning of the eradication campaign against the West Indian fruit fly at Key West, Fla., it was necessary to develop an efficient insecticide for the adults. Arsenical compounds, of which lead arsenate was the most important, have been widely used for the control of fruit flies. Copper carbonate was de-

veloped and used for control of fruit flies in connection with the eradication campaign against the Mediterranean fruit fly in Florida. Investigations at the laboratory at Mexico City developed that nicotine sulfate is effective against *Anastrepha ludens* Loew, and this material is used in spray applied for fruit flies in the Rio Grande valley of Texas. The effectiveness of nicotine sulfate as a poison for a species of *Anastrepha* suggested its use at Key West. A spray consisting of 1 gallon of nicotine sulfate (40 per cent nicotine) in 200 gallons of water, plus 10 per cent molasses, was used by the State Plant Board in 1932 against the West Indian fruit fly at Key West.

Table 1.—Fruits attacked by the West Indian fruit fly.

FRUITS ATTACKED BY *Anastrepha acidusa*

Almond (*Terminalia cattappa*)[4]
Apple (*Malus* sp.)
Barbados cherry (*Malpighia* sp.)[4,5]
Bean, string
Bell pepper (*Capsicum* sp.)
Bunch grape (*Vitus vinifera*)[4,5]
Cattley guava (*Psidium cattleianum*)
Calamondin lime (*Citrus mitis*)
Coco plum (*Chrysobalanus icaco*)[4]
Coco plum (*Chrysobalanus pellocarpus*)
Fig (*Ficus carica*)
Grapefruit (*Citrus grandis*)
Guava (*Psidium guajava*)[4,5]
Jamaica apple (*Annona cherimola*)[4,5]
Japanese persimmon
Kumquat (*Citrus japonica*)
Mango (*Manigifera indica*)[4,5]
Natal plum (*Carissa grandiflora*)[4]
Papaya (*Carica papaya*)[4]
Peach (*Amygdalus persica*)
Pear, Kieffer (*Pyrus* sp.)
Pomegranate (*Punica granatum*)[4]
Prunus americana
Rose apple (*Eugenia jambos*)
Sapodilla (*Achras sapota*)[4]
Spondias cytheria
Spondias mombin[4,5]
Spondias purpurea[4,5]
Soursop (*Annona muricata*)[4]
Sugar apple (*Annona squamosa*)[4]
Surinam cherry (*Eugenia uniflora*)[4,5]
Thevetia neriifolia[4]
Ti-Es (*Lucuma nervosa*)[4,5]
Tomato (*Lycopersicum esculentum*)
Wild hog plum (*Ximenia americana*)[4,5]

FRUITS ATTACKED BY *Anastrepha suspensa*

Calamondin lime (*Citrus mitis*)
Guava (*Psidium guajava*)
Jamaica apple (*Annona cherimola*)
Kumquat (*Citrus japonica*)
Natal plum (*Carissa grandiflora*)
Papaya (*Carica papaya*)
Wild hog plum (*Prunus* sp.)
Prunus americana
Rose apple (*Eugenia jambos*)
Spondias purpurea
Surinam cherry (*Eugenia uniflora*)

Experiments conducted at Key West by Hart[6] in October 1932 indicated that the nicotine sulfate mixture was not fully effective against the West Indian fruit fly. The flies not only succumbed very slowly in his experiments, but also many flies recovered after feeding. One fly was observed to feed nine times and to recover after each feeding. As a result of Hart's experiments it was recognized early in the work that a more fully effective insecticide than nicotine sulfate was needed.

A continuation of the study of fruit-fly baits has confirmed the superior merit of tartar emetic bait, as previously indicated in the work of the laboratory in the Canal Zone in 1932, and this conclusion has been confirmed during 1933 at other fruit-fly stations.[7] Preliminary experiments with tartar emetic at Key West indicated that the material was highly effective against the species of *Anastrepha*.

MATERIALS AND METHODS.—The materials tested at Key West were limited to those formulae or mixtures which had been widely used or were recommended for use against fruit flies. The poisons tested are listed in table 2, and the formulae are given in footnotes 8–11. All of the work was done with flies of the species *Anastrepha acidusa* reared in the insectary. The age, treatment, feeding and many other important factors relative to insects for toxicity work were known. For each experiment flies of the same treatment and age, usually 12 to 14 days, were selected. These were introduced into cheesecloth-screened cages of the

[4] Fruits which occur at Key West; others were imported from the mainland of Florida.
[5] Fruits which were highly subject to attack.
[6] **Reginald Hart,** unpublished notes.
[7] Report of the Chief of the Bureau of Entomology, 1933, p. 12.

same size. The insecticides were sprayed on guava foliage held in bottles of water to keep the leaves fresh, and the foliage was placed in a cage. The number of dead flies was observed and recorded at frequent intervals during the day. All of the tests were made in a screened insectary under natural conditions of temperature and humidity.

The results of the insecticide tests are based on 40 experiments with tartar emetic in which a total of 896 flies were used, and seven experiments each with lead arsenate and nicotine sulfate in which a total of 300 flies were used. A total of 341 flies in 18 experiments were used for checks in which there was very little mortality. The results of the insecticide tests are shown in table 2.

Table 2.—Results of laboratory tests of copper carbonate, lead arsenate, nicotine sulfate and tartar emetic used with molasses against adults of *Anastrepha acidusa*, Key West, Fla., 1933.

Material	No. Tests	No. Flies Used	Mean Time in Hours Required for Various Mortality Percentages				
			10%	*25%*	*50%*	*75%*	*100%*
Lead Arsenate[8]	7	150	35.3	41.3	45.7	52.4	65.3
Copper carbonate[9]	1	25	42.1	48	66	90	100
Nicotine sulfate[10]	7	150	17.9	25	28.3	46	50
Tartar emetic 8 lbs.[11]	19	429	3.6	8.7	14.4	21.3	27.6
Tartar emetic 6 lbs.[11]	7	179	7.3	13.9	16.3	22.3	40.6
Tartar emetic 4 lbs.[11]	11	213	8.1	15.9	21.5	28.9	49.5
Tartar emetic 2 lbs.[11]	3	75	9.3	17.3	23.7	38.4	53.2
Check (No poison)	18	341	111.3				

Results.—Copper carbonate gave a very slow rate of mortality which did not compare favorably with that obtained with the other materials, and the use of copper carbonate was discontinued after one test.

Lead arsenate at the concentration used required a mean time of 65.3 hours to cause 100 per cent mortality. The flies did not seem to feed readily on the foliage sprayed with lead arsenate.

Nicotine sulfate, at the dosage of 1 gallon to 200 gallons of water, plus 10 per cent molasses, required a mean time of 50 hours to cause 100 per cent mortality. In many instances the flies recovered after being apparently incapacitated for several hours by the nicotine. Usually more than one feeding on the foliage sprayed with nicotine was required to produce mortality of flies.

Tartar emetic, at the dosage of 8 pounds to 5 gallons of molasses and 100 gallons of water, required a mean time of 27.6 hours to cause 100 per cent mortality. Concentrations of tartar emetic ranging from 2 to 8 pounds to 100 gallons of water were used. As was to be expected, the rate of mortality was more rapid with the higher concentrations, but all of the experiments showed a high efficiency for the tartar emetic—

[8] Lead arsenate ..... 8 lbs.
Sugar ..... 50 lbs.
Molasses ..... 10 gals.
Water ..... 190 gals.

[9] Copper carbonate ..... 16 lbs.
Molasses ..... 10 gals.
Water ..... 190 gals.

[10] Nicotine sulfate (40% nicotine) ..... 1 gal.
Molasses ..... 20 gals.
Water ..... 200 gals.

[11] Tartar emetic (Potassium antimony tartrate) ..... 2, 4, 6 or 8 lbs.
Molasses ..... 5 gals.
Water ..... 100 gals.

molasses mixtures. Four pounds of tartar emetic with 5 gallons of molasses appeared to be about the most economical mixture, considering cost of material and rate of mortality, and this combination was used in the eradication campaign.

Persistence of tartar emetic.—Tartar emetic is a highly soluble material, and the length of time during which the material will persist on foliage in amounts sufficient to be toxic to the flies is dependent to a considerable extent upon the amount and frequency of rainfall. The type of foliage also seems to influence the length of time the material will persist.

In tests conducted at Key West the results indicated that under the same conditions of rainfall tartar emetic will persist in amounts sufficient to be toxic to the flies longer on foliage from trees like sugar apple, sapodilla or Ti-Es than on foliage from trees like guava or hog plum. This is probably because the foliage on the former types of trees is dense and offers more protection from weathering than is given by the open foliage on the latter types of trees.

Under conditions of rainfall at Key West, especially during the late summer and early fall months when rainfall occurs at frequent intervals, it was apparent from tests that tartar emetic will not persist in amounts sufficient to be toxic to the flies for any great length of time. The results of tests indicated that as little as .25 inch rainfall would greatly reduce the toxicity of the sprayed foliage. The results of several tests indicated that the tartar emetic may persist for a period of seven to nine days in the absence of any considerable amount of rainfall. The results of one test indicated that tartar emetic may remain effective for 14 days in the absence of any rainfall.

Foliage injury tests.—Preliminary tests of tartar emetic at Key West indicated that the material apparently would not injure foliage. During July 1933 tartar emetic was applied as a spray (tartar emetic 8 pounds, molasses 5 gallons, water 100 gallons) to four trees—avocado, guava, hog plum and sugar apple. Six applications of the material at weekly intervals were made. There was no injury of any kind to either the fruit or foliage as a result of the six applications of tartar emetic.

During the period of September 15–21, six applications of tartar emetic (tartar emetic 10 pounds, molasses 5 gallons, water 100 gallons) were made at daily intervals, except September 17, to four guava trees, a Jamaica apple tree and three rose bushes. The trees and the rose bushes were drenched with the material at each application. Not the slightest trace of injury developed on any of the foliage sprayed.

In the eradication campaign, six complete applications of tartar emetic and molasses have been made to the fruit-producing trees in Key West. No injury was observed which could be attributed to the tartar emetic.

Precautions to be taken in spraying with tartar emetic.—Tartar emetic under certain conditions may cause irritation of the skin. Tartar emetic is only slightly irritant, but the acid secretion of the follicles, especially under conditions of pronounced perspiration in a warm climate, causes decomposition with the liberation of the highly irritant antimonious oxide and other compounds. These strong irritants cause

local necrotic areas in the form of pustules resembling smallpox. These areas may become infected secondarily.

It is highly important, therefore, that the persons using tartar emetic for spraying should avoid getting any of the material on the skin. The first important consideration is to keep the operators out of the spray material. The liberal use of vaseline over the body to protect the skin from the liquid and a thorough bath at the end of each day's work will assist in preventing most of the causes of irritation. When the spraying campaign was started at Key West, severe cases of skin irritation resembling smallpox developed on two operators. After the precautions outlined above were adopted, no further trouble developed. It appears that with the proper precautions, tartar emetic is no more dangerous to use than any other insecticide.

Summary.—Investigations to obtain further knowledge concerning the hosts and the reaction to poison sprays of the two species of West Indian fruit fly, *Anastrepha acidusa* Walk. and *Anastrepha suspensa* Loew, which occurred on the Island of Key West, Fla., were conducted in 1932 and 1933. Results of oviposition experiments under cage conditions indicated that the species *A. acidusa* may successfully attack 35 different kinds of fruit and that *A. suspensa* may also attack many of the same fruits. Results of insecticide tests confirmed the superior merits of tartar emetic as a fruit-fly bait spray.

HOMOLOGS OF PARIS GREEN

II. HIGHER MEMBERS OF THE ACETIC ACID SERIES

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Search of the literature has failed to disclose any references to compounds similar to Paris green in which a fatty acid containing more than five carbon atoms in the molecule had been substituted for acetic acid. Abrahams (*1*) substituted valeric acid for acetic acid but gave no analysis of the product. The object of the present investigation was to determine whether the higher fatty acids of the acetic series form definite complex compounds with copper and arsenic similar to the compounds formed by the lower members of the series (*3*) which have the general formula $3CuAs_2O_4 \cdot Cu(acid)_2$. Ultimately their usefulness as insecticides is to be determined.

Methods of analysis.—The methods of analysis employed were based upon those given in the A.O.A.C. Book of Methods (*2*). The total arsenic was determined by the hydrazine sulfate—sodium bromide distillation method. The sample for copper determination was first ignited to destroy the fatty acid and to drive off most of the arsenic. The residue was dissolved in hydrochloric acid and the copper precipitated by boiling with sodium hydroxide. The well-washed copper oxide was dissolved in nitric acid and the copper determined by the sodium thiosulfate method. The fatty acids were determined by difference.

Copper lauro-arsenite.—Lauric acid is obtained from coconut oil. The pure acid has a melting point of 43.6° C. It is insoluble in water and is very stable. It forms metallic salts all of which are insoluble in water with the exception of the fixed alkali compounds. Copper laurate is slightly soluble in alcohol, more soluble in ether and readily soluble in warm carbon tetrachloride. The method employed in preparing the copper lauro-arsenite was as follows:

Lauric acid or refined coconut oil was saponified by refluxing with an alcoholic sodium hydroxide solution. A boiling solution of sodium arsenite was added with constant stirring to the hot soap solution, from which the other saponification products had not been separated. The mixture was diluted with warm water, phenolphthalein indicator added and dilute hydrochloric acid run in until the pink color was discharged. The mixture at this stage was kept slightly alkaline to red litmus paper to prevent the precipitation of the fatty acid. A solution of cupric chloride was added to the warm mixture with vigorous agitation. The olive green precipitate which immediately forms may be contaminated with precipitated copper oxide if the mixture of soap and sodium arsenite solutions is too strongly alkaline before the copper salt is added. The mother liquor should have a decided acid reaction to blue litmus paper when all of the copper solution has been stirred in. If alkaline, dilute hydrochloric acid is added until the reaction becomes acid. It is preferable to have the mixture of soap and sodium arsenite solutions sufficiently neutralized so that upon adding the copper chloride solution the mother liquor will become of the right acid content without the addition of more acid. The precipitated mass was heated with constant stirring until it changed from olive green to the characteristic light green color, which takes place at about 100° C or after boiling for a short time. The green was allowed to stand over night to allow complete reaction and to allow any copper oxide formed during the precipitation time to be redissolved by the acid mother liquor. The precipitate was filtered and washed free of water-soluble products. It was dried below 100° C, as the mixture softens and cakes if considerable copper laurate, which has a low melting point, is present. The dried samples were then analyzed. Compounds were made from single and double-distilled coconut-oil fatty acids, refined coconut oil and C. P. lauric acid, and the proportions of arsenic, copper and fatty acid were varied in preparing the different samples so that mixtures were obtained with arsenic content ranging from 22.77 to 42.24 per cent As_2O_3, copper content ranging from 17.12 to 24.02 per cent CuO, and lauric anhydride from 34.86 to 57.40 per cent, respectively.

None of the preparations had the composition of any rational theoretical compound. All contained an excess of the fatty acid or unsaponified fatty matter. In order to determine whether definite compounds were formed, a method was necessary for separating the unsaponified fatty matter, copper laurate and other possible impurities from the copper lauro-arsenite. Warm carbon tetrachloride was found to be a good solvent for lauric acid and related fats as well as for copper laurate. In a previous paper (*3*) it was found that the compounds $3CuAs_2O_4 \cdot Cu(acid)_2$ were not attacked by warm carbon tetrachloride

and were practically insoluble in it. The samples were therefore extracted with the solvent by placing them in a paper extraction thimble and suspending the thimble in a 500 cc. wide-mouth Erlenmeyer flask connected to a condenser. The thimble was suspended so that it did not touch the liquid carbon tetrachloride in the bottom of the flask, but was surrounded by the warm vapors. Extraction was continued slowly until the solvent had removed most of the extractable matter, when fresh solvent was put in the flask and extraction continued until no more color could be extracted. Some samples required several days of extraction to remove most of the impurities. The compounds were then dried at 100° C, ground and analyzed. In table 1 are given the theoretical composition of copper lauro-arsenite as represented by the formula $3CuAs_2O_4 \cdot CuC_{24}H_{46}O_4$, and the range of the analyses of the samples

Table 1.—Results of analysis.

Compound		Before Purification			After Purification		
		Total Copper *% CuO*	Total Arsenic *% As_2O_3*	Anhydride of Acid *% by diff.*	Total Copper *% CuO*	Total Arsenic *% As_2O_3*	Anhydride of acid *% by diff.*
Copper lauro-arsenite	Max.	24.02	42.24	57.4	25.05	45.86	30.04
$3CuAs_2O_4 \cdot CuC_{24}H_{46}O_4$	Min.	17.12	22.77	37.6	24.58	45.12	29.76
	Ave.				24.86	45.52	29.62
	Theory				*24.59*	*45.87*	*29.54*
Copper palmito-arsenite	Max.	22.12	41.03	81.43	22.9	41.78	36.6
$3CuAs_2O_4 \cdot CuC_{32}H_{62}O_4$	Min.	6.12	12.45	36.85	22.14	41.26	35.62
	Ave.				22.64	41.53	35.83
	Theory				*22.62*	*42.21*	*35.17*
Copper stearo-arsenite	Max.	23.09	34.78	79.45	22.7	40.74	37.46
$3CuAs_2O_4 \cdot CuC_{36}H_{70}O_4$	Min.	11.9	8.65	42.22	22.3	40.16	36.9
	Ave.				22.44	40.42	37.14
	Theory				*21.76*	*40.59*	*37.65*
Copper melisso-arsenite	Max.	14.77	25.63	68.85	26.88	40.8	38.57
$3CuAs_2O_4 \cdot CuC_{60}H_{118}O_4$	Min.	10.85	16.57	60.03	22.55	34.55	36.65
	Ave.				24.03	38.14	37.83
	Theory				*17.71*	*33.04*	*49.25*

before and after extraction with carbon tetrachloride. The two samples made from single distilled coconut-oil fatty acid were not considered because of discrepancies due probably to the presence of other homologous acids as impurities, forming compounds which were not extracted by the solvent. The fact that the samples containing varying percentages of arsenic, copper and fatty acid finally extract to practically identical composition, within experimental error, is conclusive proof that a definite compound has been formed and further that the ratio of copper meta-arsenite to copper laurate is three to one.

Copper palmito-arsenite.—Palmitic acid is obtained from palm oil or by the reaction of caustic potash upon oleic acid at elevated temperature. Pure palmitic acid melts at 61.5° C. It is a white finely crystalline mass, insoluble in water or dilute acid, but soluble in warm alcohol, ether, carbon tetrachloride, hydrocarbons and fixed oils. It forms metallic palmitates which, with the exception of the sodium and potassium salts, are insoluble in water. Copper palmitate is only slightly soluble in alcohol and ether, but readily soluble in hot carbon tetrachloride. The copper palmito-arsenite samples were prepared and purified in the same manner as were the copper lauro-arsenite samples. Both technical and C. P. palmitic acid were used. The proportions of arsenic, copper

and palmitic acid were varied so that mixtures were obtained containing 12.45 to 41.03 per cent As_2O_3; 6.12 to 21.92 per cent CuO; and 36.85 to 81.43 per cent palmitic anhydride, respectively. The well-washed samples were dried at 100° C, as the melting point of copper palmitate is about 120° C, and analyzed. The samples were purified by extraction with carbon tetrachloride in a manner similar to that used with the copper lauro-arsenite samples. In table 1 is given the theoretical composition of the compound $3CuAs_2O_4 \cdot CuC_{32}H_{62}O_4$ as well as the range of the analyses before and after extraction with carbon tetrachloride. The excess copper palmitate was more difficult to remove from the copper palmito-arsenite than copper laurate from copper lauro-arsenite. From the foregoing results it is evident that palmitic acid forms a definite complex compound with arsenic and copper in the ratio of three molecules of copper meta-arsenite to one molecule of copper palmitate.

Copper stearo-arsenite.—The esters of stearic acid occur extensively in nature, especially in the harder fats of the animal kingdom such as mutton and beef suet. It is also a constituent of cotton seed and other vegetable oils. Pure stearic acid melts at 69.5° C. It is a white crystalline mass, insoluble in water, slightly soluble in cold alcohol, but readily soluble in hot alcohol, ether and carbon tetrachloride. It forms a well-defined class of metallic salts, all of which, with the exception of the fixed alkali metals, are insoluble in water. Most of them are soluble in alcohol and ether. Copper stearate is slightly soluble in alcohol and ether, but readily soluble in hot carbon tetrachloride.

The copper stearo-arsenite samples were prepared and purified in a manner similar to the lauric and palmitic samples previously described, the copper, arsenite and stearic acids being varied so that mixtures were obtained with arsenic ranging from 8.65 to 34.78 per cent As_2O_3; copper from 11.9 to 23.09 per cent CuO, and stearic anhydride from 42.22 to 79.45 per cent respectively. Compounds were made from stearic acid previously purified by alcohol, which had a melting point of 54° C, and from cottonseed oil refined for medicinal purposes. The excess copper stearate required longer extraction for its removal from the copper stearo-arsenite compound than did the copper laurate or copper palmitate from their respective copper-arsenic compounds. In table 1 is tabulated the composition of the theoretical copper stearo-arsenite compound ($3CuAs_2O_4 \cdot CuC_{36}H_{70}O_4$) as well as the range of the analyses of the samples before and after extraction with carbon tetrachloride. Again it is clear that a definite compound has been formed, and that the ratio of copper meta-arsenite to copper stearate is three to one.

Copper melisso-arsenite.—Melissic acid, one of the higher members of the acetic series, is a constituent of beeswax. The pure acid has a melting point of 90° C. It is insoluble in water but soluble in warm alcohol and carbon tetrachloride. Two samples of copper melisso-arsenite were prepared from yellow beeswax and one from a purified wax made by dissolving the crude wax in boiling alcohol and separating the precipitated acid after cooling to 15° C. One sample was made using this purified beeswax. The results are tabulated in table 1. They do not agree well with the theoretical figures due to the presence of other acids, which formed

compounds with copper and arsenic that were not removed by purification.

Toxicity tests.—A few toxicity tests were conducted by the U. S. Bureau of Entomology,[1] using the mosquito and army worm larvae and the cotton boll weevil. Difficulty was encountered in applying the samples of insecticides submitted, due to their poor physical condition. They were slightly sticky and too coarse, and no satisfactory method of suspending them in water had been developed. The toxicity data will be withheld until improved preparations and better methods of suspending them in water have been tested.

Conclusions.—The conclusions to be drawn from a study of the findings of this investigation are:

1.—That lauric, palmitic, stearic and probably melissic acids form definite complex compounds with arsenic and copper.

2.—That the ratio of arsenic to copper in the compounds is the same as for those formed by the lower homologs, namely, three molecules of copper meta-arsenite united with one molecule of copper salt of the fatty acid, from which the inference may be drawn that all the acids of the acetic series form compounds with the general formula $3CuAs_2O_4 \cdot Cu(acid)_2$.

3.—No conclusions as to toxicity are possible due to the meagre data collected and to the poor physical condition of the test samples.

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VALUE OF IMPROVEMENTS IN JAPANESE BEETLE TRAPS AND BAIT

AS MEASURED BY THE NUMBERS OF BEETLES CAUGHT

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The first bait trap designed to capture the Japanese beetle was employed in 1924 and since that time extensive tests have been conducted to increase the effectiveness of the original "standard" device (*5*). Many improvements have been made in the structure of the trap and in the bait employed to attract the insect. As the traps can be tested only in a very limited period each year while the beetles are abundant—in the most favorable years for not more than six weeks—but little experimentation was possible each year, and therefore the changes through the 10 years have been gradual. A further limiting factor has been the cost of the trap and the necessary bait, for it was real-

[1] Tests made by M. C. Swingle of the Division of Control Investigations, and G. L. Smith, Division of Cotton Insects Investigations, Bureau of Entomology and Plant Quarantine.

ized early in the work that expensive equipment, no matter how effective it might be in catching beetles, would be used by the general public only to a very limited extent.

Accounts of certain of the improvements in the trap and bait have already been published and are a matter of record; others have been mentioned only in reports. The question is often raised, however, as to the exact value of these changes in respect to the increased effectiveness

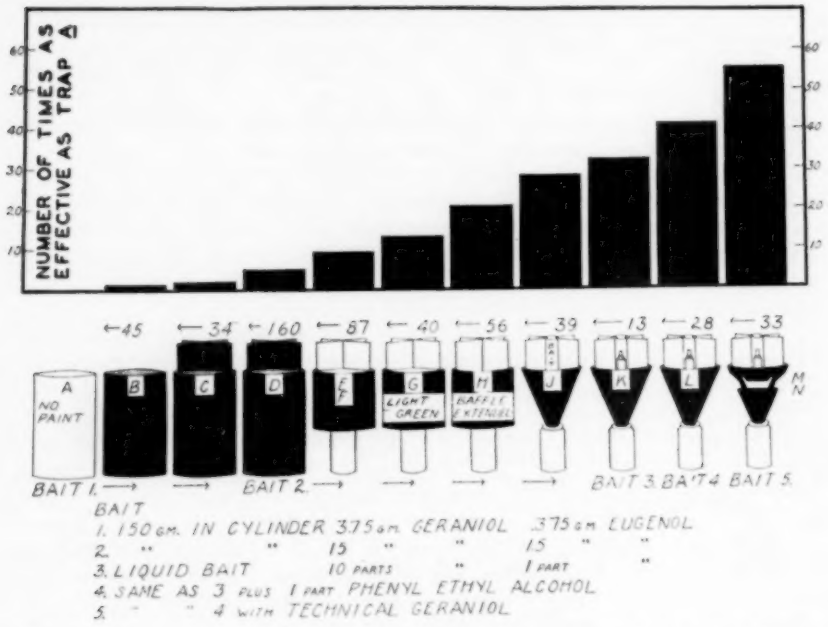

Fig. 1.—Improvements in trap and bait over original device and the value of these changes in respect to increased effectiveness in catching beetles. Shaded portions of trap denote green paint and unshaded portions white. The base line of the column diagram above indicates the effectiveness of trap *A*, with which all the other traps are compared.

of the trap in catching beetles, and also regarding the percentage of those insects attracted to a trap that are actually captured. The purpose of this paper is to describe and summarize briefly the improvements made and to give all available information in answering the questions just mentioned.

Improvements in trap and bait.—The various steps in the development of the trap and bait are given in chronological order, and are shown graphically in figure 1, where the letters *A*, *B*, etc., refer to the respective traps or bait changes described in the following paragraphs. The literature citations with the discussions of each change that follow refer to the first published record of a particular device. In several cases the published data were preliminary in nature, and further tests resulted

in a revision of the value of certain improvements; many of these tests were conducted by the writer, and the data are unpublished.

(*A*) The trap used in 1925 (*1*) was cylindrical, of unpainted galvanized iron, had no baffle, and utilized a bran bait located within the cylinder. Each charge of bait used in this trap contained 3.75 grams of geraniol and .375 grams of eugenol. Such traps without the bait usually retailed at $2.50 to $3 each.

(*B*) The same trap painted green (*6*) when tested in comparison with trap (*A*) captured 45 per cent more beetles than the latter.

(*C*) A baffle was the next improvement added (*5*). The green-painted trap with a four-winged baffle projecting 4 inches above the funnel captured 34 per cent more beetles than the same trap without a baffle. This improvement caused the capture of many beetles that formerly flew over the trap. Obviously, no more beetles were attracted to such a device than were lured to trap *B*. This improvement, therefore, is intimately connected with increased effectiveness in catching insects which are attracted.

(*D*) The green cylindrical trap *C* when equipped with a charge of bran bait containing 15 grams of geraniol and 1.5 grams of eugenol (*6*) captured 160 per cent more beetles than the same type of trap with the bait as given under *A*.

(*E*) The length of the metal cylinder was reduced one half and a jar beetle container substituted.[1] This improvement was for convenience in operation and had no bearing on effectiveness in attracting or catching beetles.

(*F*) Traps of type *E* with the cylinder green, but with the inside of the funnel and the entire baffle painted white, captured 87 per cent more beetles (*7*) than similar devices painted all green.

(*G*) Traps of type *F* with the cylinder painted in lighter shades of green and with the bait as given under *D* captured 40 per cent more beetles than the same trap similarly baited but painted medium or dark green.

(*H*) The light-green and white trap *G*, but with the baffle projecting 2 inches into the funnel (*2*), captured 56 per cent more beetles than the same trap without the baffle extension. This change prevented beetles from flying under the baffle and out the other side of the trap. It did not affect the number of insects attracted.

(*J*) Locating the bait container above the funnel and between the four wings of the baffle resulted in 39 per cent more beetles being captured than were taken in traps where the bait was located within the cylinder. This materially reduced the cost of the trap by dispensing with the cylinder.

(*K*) Trap *J*, in which the bait container is located in the baffle above the funnel, with bait in liquid form consisting of 10 parts of geraniol and 1 part of eugenol vaporized by a wick or impregnated in cakes of pumice captured 13 per cent more beetles than the same trap with bran bait (*3*). This reduced the cost of bait materials.

(*L*) Phenyl ethyl alcohol added to the bait described under *K* at the

[1] Designed by C. H Hadley.

rate of 1 part to 20 parts of geraniol and 2 parts of eugenol increased the number of beetles captured by 28 per cent as compared with similar bait without phenyl ethyl alcohol.

(*M*) Traps of type *J* with four apertures in the walls of the funnel captured 33 per cent more beetles than traps without apertures (*4*). This construction tends to increase the catching area of a trap.

(*N*) The cost of operating the latest trap, namely, type *M*, with the bait as given under *L* has been further reduced by using technical geraniol in place of a more highly refined grade. The technical material is fully as attractive as the purer product and costs less than two-thirds as much. The later devices are sold at retail prices with bait at approximately $1.

An indication of the improvements in these successive steps is shown by the increased catch as measured in percentage of the preceding type of trap and bait.

PERCENTAGE OF INCREASE IN NUMBER OF BEETLES CAPTURED

B over *A* 45	*F* over *E* 87	*K* over *J* 13
C over *B* 34	*G* over *F* 40	*L* over *K* 28
D over *C* 160	*H* over *G* 56	*M* over *L* 33
E over *D*	*J* over *H* 39	*N* over *M* .....

If trap *A* is assumed to have an efficiency of 1 and trap *B* 1.45, and the succeeding increases are figured on this basis, trap *M* is found to be nearly 55 times as efficient in catching beetles as the trap used in 1925.

The 1934 trap and bait have never been tested directly in comparison with the earliest device and the bait used at that time, and it is doubtful if such a test would be conclusive, owing to the fact that no analysis is available concerning the grade of geraniol used in these early traps. Some confirmation of the results can be made, however, along a somewhat different line.

In 1926 a trap of type *A* located near Riverton, N. J., captured nearly 2 quarts of beetles in a single day. This was by far the greatest number captured in any one trap during that year. The infestation in the vicinity of Riverton was at the peak during that period.

During the summer of 1933 several traps of type *L*, which are not so effective in catching beetles as type *N*, operated by the New Jersey Department of Agriculture in Salem county, N. J., captured 40 quarts each in a single day.[2] The writer feels that the infestation in the vicinity of these traps was no greater than that near Riverton in 1926. On this basis, the trap *L* is at least 20 times as effective in catching beetles as the 1925 trap, and the latest type, *M* or *N*, should be 27 times as effective.

Effectiveness of traps in catching beetles which are attracted.—Richmond & Metzger (*5*), as a result of limited observations, reported that the 1925 trap caught 30.3 per cent of the beetles which were definitely attracted to that arrangement. If these early observations had been correct, the stated effectiveness of the 1934 trap would be absurd. Further observations by the writer have, however, produced additional data on this subject.

[2] **Rex, E. G.** Director of Japanese beetle suppression, New Jersey Department of Agriculture. Unpublished results.

The only known method of determining the effectiveness of a trap is to count the beetles which are attracted and those which are captured because it is impossible even to estimate the number of insects which may be within the zone of attraction. This can be done when only a few beetles are attracted at any one time. Such a situation exists in areas of light infestation or, in the case of moderate or heavily infested localities, very early in the morning or late in the evening when few beetles are flying. Under such conditions from 30 to 75 per cent of the attracted beetles have been captured by traps of various types. As the number of beetles which are attracted becomes greater the percentage of those captured drops appreciably.

When, however, as many as 25 beetles are flying around a trap, it is impossible for the most skilled observer to follow accurately any one individual, and the number of beetles attracted cannot be determined with any degree of accuracy because many beetles are constantly coming and going.

It is the opinion of the writer that no definite statement can be made regarding the effectiveness of traps in areas of heavy or even moderate infestation, for the reasons just given. Conclusions arrived at after 10 years' experience with traps are that these devices are more efficient in lightly infested districts, and that two traps placed 10 feet apart, while not attracting twice as many beetles as one trap, will capture a greater percentage of the beetles attracted.

Increased effectiveness in attracting beetles compared with increased efficiency in capturing beetles so attracted.—The improvements in the trap and bait can be grouped into two main classes as follows: (1) Those which result in catching a higher percentage of the beetles which are attracted, but which do not increase the number of beetles attracted. These are represented by the improvements described under *C*, *H* and *M*. (2) Those improvements which increase the number of beetles attracted to the trap, but which may or may not increase the number actually captured. Examples of such improvements are illustrated by *D*, *F* and *L*.

Assuming that two types of traps were equally effective in catching beetles, it is evident that the device which attracted the greater number of beetles would be more effective in reducing an infestation than a trap which attracted a smaller number. Despite the tremendous improvement over earlier devices, the 1934 trap will not attract all the beetles in its immediate vicinity, and its effectiveness is naturally dependent upon favorable weather conditions.

The improvements referred to in the second class have probably been of more importance than those mentioned in the first, because even when the latest trap is used in heavily infested areas more beetles are attracted than are captured. The greater effectiveness over the 1925 device is, therefore, the result of a considerably increased attraction and a smaller increase in the capacity of the trap to catch the insects thus attracted.

Summary.—Tests conducted over a period of 10 years with Japanese beetle traps have resulted in a considerable improvement of such de-

vices in respect to attracting beetles and to capturing insects thus attracted.

Data indicate that in an equal infestation, the 1934 trap is probably capable of capturing 55 times as many beetles as the device used in 1925.

In lightly infested areas traps capture a higher percentage of the beetles which are attracted than in regions where the beetle is present in great abundance.

Improvements in bait have not resulted in a trap which will attract all the beetles in the immediate vicinity, nor have the improvements in the trap resulted in one that will capture all the beetles which are attracted.

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LYGUS BUGS IN RELATION TO OCCURRENCE OF SHRIVELED ALFALFA SEED

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In the production of alfalfa seed in Utah a considerable amount of brown, shriveled and misshapen seed is formed which varies from year to year apparently with differing seasonal and environmental conditions. Alfalfa seed growers and others interested in the crop have questioned the cause or causes of the occurrence of this poor quality and almost valueless seed. During threshing of the seed much of that which is shriveled is blown over into the chaff and largely escapes the notice of many farmers. Most of that remaining in the threshed seed is removed in the recleaning operation. Annual losses due to the failure of all seed to develop properly are frequently much more than is generally realized.

During the past three years the Utah Agricultural Experiment Station has made some investigation of the relationship of certain alfalfa-infesting insects to the production of alfalfa seed. The purpose of one phase of this investigation has been to ascertain whether or not *Lygus* bugs (*Lygus hesperus* Knight and *L. elisus* Van D.), which occur in great numbers in practically all alfalfa seed fields, bear any relationship to the

occurrence of shriveled seed and through it the reduction of both quality and quantity of alfalfa seed yields. During the summers of 1932 and 1933 the work was done on the Uintah Basin substation farm, while in 1934 it was conducted at Logan. Alfalfa plants were selected upon which seed-pod formation was apparently normal; these plants were growing in hills, rows, or in a thin stand in the open field.

Table 1.—Results of encaging 100 young alfalfa pods with *Lygus* bugs for 48 hours (13 replications, 1932).

Bug Infestation	No. Seeds	No. Plump Seeds	Per Cent Plump Seeds	No. Shriveled Seeds	Per Cent Shriveled Seeds
5 *Lygus*	1363	1024	75.13	339	24.87
10 *Lygus*	1167	801	68.64	366	31.36
20 *Lygus*	1265	757	59.84	508	40.16
0 (Check)	1433	1037	72.37	396	27.63
Uncaged check	1223	808	66.07	415	33.92
Total	*6451*	*4427*		*2024*	

For the purpose of encaging the insects on growing alfalfa stems wire-screen cages were used. These cages were constructed from 14-mesh wire window screening and scrim netting. Cylinders 4.5 inches in diameter and 10 inches long were made from the wire screen; on each end of these cylinders a scrim-netting sleeve 6 inches in length was attached. The sleeves served as an entrance to the cage, for closing it around the bases of the alfalfa stems and for anchoring the cage to a supporting stake driven into the ground, thereby holding the stems in an upright position and protecting them from being broken off.

Table 2.—Results of exposing five racemes of young alfalfa pods until ripe to *Lygus* bugs (10 replications, 1933).

Bug Infestation	No. Seeds	No. Plump Seeds	Per Cent Plump Seeds	No. Shriveled Seeds	Per Cent Shriveled Seeds
1	1544	1208	78.23	336	21.77
2	1151	759	65.94	392	34.06
4	843	593	70.34	250	29.66
0	1140	927	81.32	213	18.68
Total	*4678*	*3847*		*1191*	

Cages were arranged on stems of the alfalfa plants in sets of four. Within each cage was enclosed a stem bearing a specific number of young newly-formed pods or racemes of such pods. Three cages in each set were infested with adult *Lygus* bugs while the fourth cage remained uninfested and served as a check. The number of pods, racemes of pods or buds and flowers encaged, the number of bugs put or kept in each cage, and the period of infestation are specified in tables 1, 2 and 3.

1932.—At the outset (August 1932) the chief purpose of this phase of the investigation was to ascertain whether or not, during a short period of infestation, the bugs were capable of affecting the seed quality. To obtain this information an experiment was performed in which growing alfalfa stems bearing 100 young pods were encaged within each of the four wire-screen cages. Into three of these cages were introduced 5, 10 and 20 *Lygus* bugs, respectively, where they were left for 48 hours and

then removed. As already stated, the fourth cage served as a check. After the bugs were removed from the cages, the latter were left in place on the stems until the pods were ripe so as to protect the seeds from further attack by the bugs. This test was replicated 13 times. When ripe, the pods were carefully picked and hulled by hand. Seeds were examined with a binocular microscope and the number of plump and shriveled seeds from each of the four cages tabulated. Results were calculated on a percentage basis (1) because of the variable number of seeds which

Table 3.—Results of encaging alfalfa stems, each bearing two racemes of buds, flowers and young pods, until ripe with *Lygus* bugs, 1934.

Bug Infestation	No. Seeds	No. Plump Seeds	Per Cent Plump Seeds	No. Shriveled Seeds	Per Cent Shriveled Seeds
		12 Replications			
1	784	547	69.77	237	30.23
2	742	508	68.46	234	31.54
4	653	300	45.42	353	54.58
0	800	699	87.37	101	12.63
Total	*2979*	*2054*		*925*	
		11 Replications with Ratio of Infestation Doubled			
2	484	206	42.56	278	57.44
4	504	157	31.15	347	68.85
8	673	182	28.04	491	71.96
0	654	586	89.70	68	10.30
Total	*2315*	*1131*		*1184*	
		10 Replications with Two Racemes of Pods Only			
1	433	286	66.05	147	33.95
2	446	239	53.59	207	46.41
4	432	182	42.13	250	57.87
0	628	563	89.65	65	10.35
Total	*1939*	*1270*		*669*	

naturally form in a specific number of pods, and (2) because of impossibility to count the seeds within the young pods at the time they were infested with the bugs. A summary of the results obtained in this test is given in table 1.

1933.—In August 1933 alfalfa stems bearing five racemes of young newly formed pods, together with a few buds and flowers, were encaged as described in the tests of 1932. Into three cages were introduced 1, 2 and 4 *Lygus* bugs, respectively, the fourth cage serving as a check. A few buds and flowers were left on the encaged stems to provide the bugs with a choice of alfalfa plant parts upon which to feed, similar to open-field conditions, with the exception of the cage. Bug infestation was kept constant from the time of early pod formation until the seeds became ripe, a period of approximately three weeks; this was accomplished by checking on the bugs every other day and replacing those which had died. Summarized results for the 1933 study are included in table 2.

1934.—In the 1934 studies, part of the cages were provided with pods, buds and flowers; the remainder of the cages were provided with pods only. Approximately two thirds of the cages were infested with 1, 2 and

4 bugs, respectively, whereas the remainder were infested with 2, 4 and 8 bugs, as indicated in table 3, together with the resulting production of plump yellow seeds and shriveled brown seeds, respectively.

Statistical analyses of the original data, briefly summarized in tables 1, 2 and 3, show the following:

1.—In 1932 the variance in the occurrence of shriveled seed was only slightly influenced by bug infestation during the short exposure of 48 hours. There was a small increase in the number of shriveled seeds, which was directly attributable to the bug factor.

2.—Under conditions prevailing during the period of the test in 1933 there was no significant influence on the quality of the seed resulting from the bug infestation. This may be accounted for in part, perhaps, by the fact that within three or four days after the experiment had been set up in the field all of the alfalfa surrounding the tenth acre plat upon which the cages were placed was cut for hay. The alfalfa on the entire farm was heavily infested with *Lygus* bugs, and when that surrounding this particular experimental plat was cut the bugs concentrated on it with the result that all alfalfa plants, including those upon which the insect cages were arranged, were seriously injured. This bug invasion introduced an unexpected factor which apparently influenced the normal course and results of the experiment.

3.—In 1934 the bugs constituted a highly significant factor in the production of increased numbers of shriveled seeds. In this connection it should perhaps be stated that the *Lygus* infestation in the field where this experiment was performed was almost directly opposite to that which prevailed in the 1933 field. In 1934 the experimental plants were among a thin stand of volunteer alfalfa which had grown after an old alfalfa patch had been plowed up. The set of pods on these plants was particularly good. The field was entirely isolated from other alfalfa fields and bug infestation was negligible.

Conclusion.—Results obtained during the course of this experiment indicate that the feeding of *Lygus* bugs, even for a short period of time, increased the number of shriveled seeds. The increase was generally in direct proportion to the degree of bug infestation. There is also some indication that the total number of seeds may be reduced as a result of the feeding of these bugs. Furthermore, these results point to a likelihood of smaller yields and of poorer quality alfalfa seed, resulting, partially at least, from heavy infestations of *Lygus* bugs in seed fields. The fact that an appreciable amount of shriveled seed was produced on the stems within the check cages where they were protected from *Lygus* bugs is evidence that these bugs are not the exclusive cause of shriveled alfalfa seed and that other environmental factors contribute to its production.

THE OREGON QUARANTINE ORDER relating to gladiolus thrips was revised on February 28, changing the formulas and methods of treatment required for the entry of gladiolus corms into the state or their movement therein.

COLD-WATER TREATMENT AS A CONTROL FOR THE SUGAR CANE BORER

E. K. Bynum and August I. Balzer, *U.S.D.A., Bureau of Entomology and Plant Quarantine*

In Louisiana and Texas the sugar cane borer *Diatraea saccharalis* Fab. hibernates as a larva in cane trash, cane stubble, planted cane stalks, cornstalks, sorghums and large uncultivated grasses. The number of borers appearing in the spring is dependent upon the number that survive the winter in these various materials.

Investigations have been conducted for a number of years to find a method of seed-cane treatment that would destroy the borers therein, thus eliminating this source of spring infestation and making it safe to ship seed cane from infested to noninfested territory.

Table 1.—Mortality of *Diatraea saccharalis* larvae and pupae in sugar cane immersed in fresh water at Houma, La.

Date Immersed	Variety	Pounds of Cane	Hours Immersed	Average Temperature (F) of Water Recorded	Average Temperature (F) of Air Recorded	No. That Never Showed Any Sign of Life		Live Stages Found: Active when Removed from Cane		Active 3 days after Removal from Cane		Percentage Mortality
						Larvae	*Pupae*	*Larvae*	*Pupae*	*Larvae*	*Pupae*	
12-13-30	POJ 213	500	72	58	56	44	0	89	0	119	0	27
9-25-31	POJ 213	300	72	87	84	27	1	0	0	0	0	100
10-16-31	POJ 213	290	72	78	77	30	0	7	1	4	1	86.8
10-30-31	POJ 213	400	72	69	65	48	0	0	0	4	0	92.3
9-21-34	Co. 281	290	96	86	84	7	4	0	0	0	0	100
9-21-34	Co. 281	650	72	86	84	15	7	0	2	0	2 adults emerged	92.2
2- 8-35	POJ 213, 234, 36M	465	72	63	63	8	0	10	0	6	0	66.6
2- 8-35	POJ 213, 234, 36M	339	120	63	63	5	0	2	0	0	0	100
3-28-35	CP 807	345	96	74	74	4	1	0	0	0	0	100
4-11-35	CP 28-19	333	96	70	68	1	1	0	0	0	0	100
4-11-35	Co. 281	514	96	70	68	2	0	0	3	0	3 2 adults emerged	60
4-19-35	Mixed	105	96	77	76	2	1	0	0	0	0	100
4-19-35	Co. 290	275	96	77	76	1	0	0	0	0	1 adult emerged	50

In 1928, T. E. Holloway and W. E. Haley[1] reported the results of experiments by them which showed that all borers in seed cane were dead after 72 hours' immersion in water at ordinary temperatures.

The present authors have conducted experiments with this cold-water treatment to determine its effectiveness on new varieties of cane and at various dates of treatment. These experiments were conducted over a period of five years. Results were disappointing since both writers discovered independently that the treatment did not kill all of the borers. A small percentage of them survived in seed cane immersed for periods longer than 72 hours.

The cane was kept completely submerged during the entire length of the treatment. At the conclusion of the treatment the cane was immedi-

[1] U.S.D.A. Tech. Bul. 41: 72.

ately removed from the water and examined soon afterwards. All borers and pupae found were carefully examined and retained for further observations. In most cases these borers and pupae appeared to be dead, the larvae exhibiting a water-soaked condition. Some of them remained inactive for several days, but later revived. In most cases the borers surviving the treatment were kept under observation for as long as one or two weeks or until they commenced feeding or appeared normal.

Table 2.—Mortality of *Diatraea saccharalis* larvae removed from host plant and afterwards immersed in fresh water for various lengths of time, Beaumont, Tex.

Source of Borers	Date Immersed	Hours Immersed	Number of Larvae Immersed	Condition	Percentage Mortality
Corn	9–29–30	72	27	Active	70.5
Sugar cane	11– 6–31	72	30	Resting	60
Sugar cane	11– 6–31	96	24	Resting	87.5
Sugar cane	11– 9–31	48	35	Resting	68.6

Some of the borers left the cane during the treatment, but most of these remained under water either on the cane or sank to the bottom of the tank. All of the borers found outside of the cane were kept separate or not counted. At Houma the cane was treated in tanks large enough to hold several hundred stalks of cane at a time.

Results of cold-water treatments are given in tables 1–3.

Table 3.—Mortality of *Diatraea saccharalis* larvae in seed cane immersed in fresh water for 72 hours, Beaumont, Tex.

Date Immersed	Variety	Date Dissected	Number of Stalks Dissected		Number of Live Larvae		Number of Dead Larvae	
			Immersed	Check	Immersed	Check	Immersed	Check
10–11–30		3–18–31	50	50	0	3	0	0
10–17–31	POJ 213	10–20–31	50	50	1 and 2 pupae	21	2	0
10–17–32	POJ 213	10–24–32	100	100	2	40	2	0

The results of these experiments, conducted independently at two locations, definitely show that the immersion of sugar cane for 72 hours in water at ordinary temperatures gives only a partial kill of the borers. This treatment cannot be recommended for treating infested sugar cane destined for borer-free territory. The mortality is high enough to give partial control, and the treatment might be advisable as a plantation practice under some conditions.

MASS LIBERATION OF AN ORIENTAL FRUIT MOTH PARASITE

Derrill M. Daniel, *New York State Agricultural Experiment Station, Geneva*[1]

The usual procedure in attempting the control of an insect pest by means of its parasites is to establish small colonies of the beneficial spe-

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal paper 114, Dec. 11, 1935.

cies throughout the area of infestation. These few individuals are supposed to multiply and spread, thus bringing about a reduction of the injury done by the pest. This procedure may require a considerable period of time to effect appreciable control. Every entomologist concerned with any biological control project probably has longed for an occasion to test the feasibility of inundating a more or less isolated area with the parasites in an attempt to effect an immediate reduction in injury. Such an opportunity was afforded the writer in 1933 in connection with the program of biological control of the oriental fruit moth at the New York State Agricultural Experiment Station.

During the two or three years immediately preceding the season of 1933 the infestation of the oriental fruit moth in the peach plantings of the White Springs farm at Geneva had increased to the point where

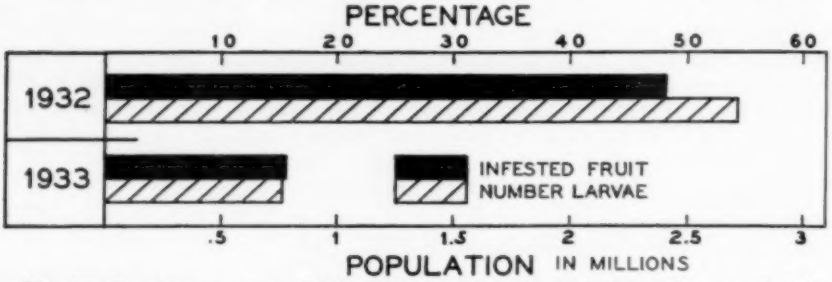


Fig. 1.—Graphic summary of infestation and larval population at harvest time in White Springs orchard. Black columns read up, checkered columns read down.

about one half of the fruit was injured in 1932. The planting consisted of a solid block of 72 acres on which approximately 9000 trees were then growing. These trees were mostly of the Elberta variety and were from 10 to 20 years of age. The orchard was far enough removed from neighboring plantings so that over a short period no appreciable influx of moths need be expected. On July 14, 1932, a colony of *Macrocentrus ancylivorus* Rohwer, consisting of 200 females, was liberated in this orchard. Twig collections made previous to this date had yielded no specimens of this species. Collections of twig-infesting larvae throughout the remainder of the season showed that the parasite had become established. Examination during the harvest period disclosed the fact that 48.34 per cent of the fruit was infested by the oriental fruit moth. By counting the number of fruits on representative trees throughout the entire orchard it was estimated that 5,625,000 were produced. The number of oriental fruit moth larvae present at harvest time in 1932 was therefore reckoned at approximately 2,720,000 (5,625,000×48.34 per cent), fig. 1.

During June of 1933 extensive collections of twig-infesting larvae were made. These collections showed *M. ancylivorus* to be present and well distributed over the orchard, but that the percentage of parasitism was below five. During the two-month period June 30–August 31 some 12,000 specimens of *M. ancylivorus* were liberated. Press of other work pre-

vented accurate determination of the percentage of parasitism during this period. However, at harvest time the same fruit counts were made as in 1932. Estimated production was 4,680,000 fruits of which 15.96 per cent were infested. The population of oriental fruit moth larvae present at harvest time in 1933 was therefore approximately 750,240, fig. 1. This was a reduction of 72 per cent and was almost two million less population than in 1932. In this connection it is recorded that three nearby orchards which received liberations in 1932 showed no such reduction, since the infestations were practically the same in 1933 as they were in 1932. This fact is important since it is realized that figures on population such as those given above are more or less approximations and should have supporting data.

It would have been very gratifying to have secured data on this orchard in succeeding years, but the experiment came to an abrupt end following the subzero weather of the winter of 1933–34. Practically all of the trees in this entire block were killed outright or injured so severely that they were removed during the winter of 1934–35. Although this experiment was not carried over as long a period as might appear desirable, it covers a point in biological control on which data are scarce and therefore publication seems desirable. This experiment cannot now be repeated in New York because practically every peach orchard at the present time contains *M. ancylivorus* either through liberation or spread from colonized areas and the fruit moth population has fallen too low for mass liberations to be of benefit. If opportunites are afforded in some other important peach section in another state, a similar test conducted for several years would yield information much needed on one phase of biological control.

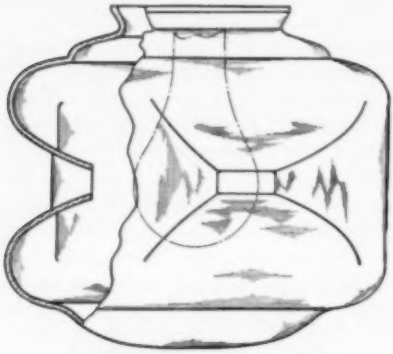
Scientific Notes

Lizard Aids in Range Insect Control.—A study of the food habits of the common sagebrush swift *Sceloporus g. graciosus* (B. and G.) was made to determine its general usefulness in lessening the number of injurious insects in the grazing area between Clover and Orr's Ranch, Tooele county, Utah. (Fisher's Pass was included in the cross-section.)

A microscopic examination of 304 sagebrush swift stomachs showed the following insect material to be recognizable: Collembola one; Orthoptera 195, 108 grasshoppers being contained in 87 stomachs, the most common forms being 11 *Melanoplus femur-rubrum* and 12 *M. mexicanus*, one Tettigoniidae and three camel crickets; Isoptera 88; Neuroptera 10, six of which were chrysophid larvae; Hemiptera 72, four being *Nysius ericae*, eight Pentatomidae, five *Thyanta rugulosa*, two *Lygaeus*, and one *Corizus;* Homoptera 109, twenty-six being leafhoppers, of which ten were *Opsius tenellus* and eight *Agallia*, 65 aphids contained in five stomachs, two Cercopidae and one Fulgoridae; Coleoptera 218, of which 93 were Chrysomelidae, seven Curculionidae, 27 Coccinellidae, 17 Carabidae, two Scarabaeidae and one Meloidae; Lepidoptera 77, of which 58 were caterpillars, contained in 47 stomachs; Diptera 19, of which three were *Chloropisca glabra*, one Asilidae, one Culicidae, two Sarcophagidae and one Muscidae; Hymenoptera 897, 795 of which were ants, contained in 139 stomachs, two Andrenidae, two Vespidae, one Sphecidae, one Ceratinidae, one Pompilidae and one *Astata*. In addition to the insects there were 16 spiders, 40 roundworm parasites and one scorpion. Of the 304 stomachs examined, 16 contained only unidentifiable insect fragments, while 21 others were completely empty. A little sand or one or more very small pebbles were frequently found in stomachs, these and a few dry plant fragments apparently being taken by accident, in connection with the investigation on arthropod prey.

GEORGE F. KNOWLTON and CLYDE F. SMITH, *Utah Agricultural Experiment Station*. 1-18-36.

A Novel Light Trap.—For several years the writer has been interested in collecting and studying moths of the family Noctuidae. Since most of these fly at night it is necessary to devise traps and baits which will attract them. Light traps are very effective and in some places bring better results than baits. Two brothers, S. A. and R. E. Wentzell of Greensburg, Pa., have patented a trap which was used by the author in the summer of 1935. Essentially the trap is a globe such as one would place over a kitchen or porch light. It differs from the ordinary globe in several respects. The most important difference lies in the fact that the sides are pierced by three slots. The insect enters through the slots and is killed by the heat generated by the electric light. It was designed primarily to catch house flies and other troublesome flying insects about the house. The writer tried one on his kitchen light for a few weeks during the month of October and found it reduced the fly population in that room. As a porch light it should be even more effective since there are seldom light-colored walls about porches and the insects would be more likely to go directly to the light, not having any light surface upon which to rest. The trap has the following points in its favor: (1) it will not be expensive as it serves a double purpose, that of trap and a light, (2) it is safe, for no poisons are used in its operations, (3) it works, for on good collecting nights over a thousand specimens have been taken by it, (4) it is clean. Many traps litter the area beneath them with the remains of destroyed insects.



Globe Light Trap, Showing Slots for Insect Entrance

One of these traps was operated during the month of August 1935 on a back porch. During this time records were kept of temperature and other weather conditions. It is hoped that further experimentation can be carried on under slightly different conditions and more complete data can be compiled.

In general the writer noted a definite relationship between weather conditions and the night flight of insects. At least four important factors appear to influence their activity. In the order of their importance these are (1) temperature, (2) moisture, (3) wind, (4) clouds.

Temperature.—Whenever the thermometer went below 70° F the catch was small. Above this there was an increase in the number of insects captured, with the optimum temperature about 85° F.

Moisture.—These records need to be checked and more accurate data are necessary but in general the higher the humidity the better the catch. Even light warm rains did not prevent flight. Heavy showers however stopped all flight and insects stayed under shelter for some time after the weather cleared.

Wind.—High winds were very unfavorable to flight unless the other conditions were exceptionally good. The best catches were made when there was no wind.

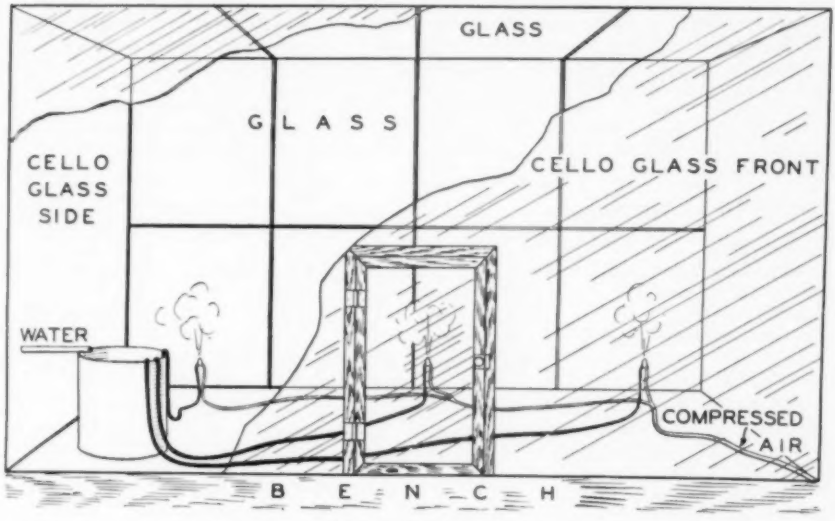
Clouds.—A cloudy sky seemed best for insect activity but this factor depended much upon the other factors already mentioned. Usually moonlight nights were very unfavorable unless other conditions were very good.

Of all the factors mentioned above, temperature and moisture were of prime importance and when these were of optimum degree the catch was sure to be fairly good.

Like most traps there was no discrimination as to what would be caught. Anything small enough to go through the slots would be captured and killed. By far the greatest number were hemiptera, mostly Jassidae. Parasitic hymenoptera were next in abundance and third in order were small coleoptera. The lepidoptera were in fine condition considering the fact that they were mixed up with a number of hard-bodied insects. Many of the lepidoptera were the adults of cutworms. Since this was the case it may indicate that the trap, or one like it, could be used to kill these noxious insects before they have had a chance to lay their eggs. The jassids also are of economic importance and their capture in large numbers may also reduce this garden menace. Before one commits himself on this point, further observations and study must be made.

HARRISON M. TIETZ, *Pennsylvania State College, Department of Zoology.* 1-10-36

Fog Chamber: A Technique for Determining Spray Injury to Growing Plants under Laboratory Conditions.—Observations on the injury that often occurs on the foliage and fruit of plants sprayed with certain insecticides and fungicides indicate that under field conditions injury normally appears following periods of rain or high humidity for six to 48 hours. Especially during periods of foggy weather the moisture that accumulates on the sprayed fruit and foliage drips off very slowly, if at all, and this permits chemical activity to proceed rapidly and for relatively long periods of time on the sprayed surface. Also the plant itself, during wet periods, becomes filled with water to the extent that gutation may occur. Under conditions like this when practically no evaporation takes place from the stomata and the plant may be forcing liquid water out through its leaves, a continuous column of water may extend from the sprayed surface into the interior of the plant. This aqueous connection may allow any soluble material on the plant to diffuse into the plant. These possible reactions to wet weather indicate how, in the presence of excess



Laboratory Fog Chamber

water on and enveloping the plant, certain sprays may produce chemically active substances that will injure plant tissue.

An adaptation of these reactions to laboratory conditions has given a technique that yields information on foliage injury rapidly in the laboratory.

To determine injury, sprayed plants are placed in a fog chamber for 24 to 48 hours. A constant fog is maintained in the chamber by means of atomizer jets operated by a constant water supply and compressed air.

In the construction of a fog chamber a section of greenhouse bench is used, as shown in the figure. The bench, side and top of greenhouse make three sides of the chamber. The other sides may be constructed of "cello-glass" (screen wire covered with a cellulose product). A door is provided in one side for moving the plants into and out of the chamber. In a chamber so constructed approximately normal greenhouse lighting and temperature control is maintained. For a chamber 5 feet square three atomizer jets will maintain a constant fog.

Water is supplied to the jets by means of independent rubber tubes leading from a vessel of water that is kept full by a connection with a laboratory faucet. Compressed air from a laboratory air line keeps the atomizer jets operating constantly.

For operation of the fog chamber the air and water supply are put into operation; the sprayed plants are installed in the case and left for the desired exposure to humid conditions. Readings on injury can be made during exposure and at any later dates.

E. R. McGovran and M. D. Farrar, *Illinois Natural History Survey*. 2-27-36

Control of the Potato Leafhopper *Empoasca fabae* on Dahlia with Flour, Talc and Infusorial Earth.—Dahlias grown in Michigan have suffered from attacks by *Empoasca fabae*, which causes tip burning of leaves and dwarfs growth. Certain varieties are relatively resistant while others are extremely susceptible.

The potato leafhopper appears early in the season and feeds on the succulent growth of a wide range of host plants. By the time dahlia plants are getting well established, the leafhopper population has built up to a degree where it is a real factor, and winged adults fly into gardens and fields where they feed on cultivated plants. The brood destructive to dahlias appears late in July or early in August, and the adults feed on the foliage and insert their eggs into the main veins of the leaves.

Since this insect has sucking mouthparts the control measures are limited to contact sprays or to repellents. During the growing season of 1935 a series of experiments was conducted in a large commercial dahlia field with the idea of determining effective control. The planting consisted of several hundred varieties, and such varieties as appeared to be suffering most from the attack of leafhoppers were selected for experimental purposes. Fifteen plants were used for each set of sprays or dusts. The plants treated were scattered through the field and for each set of experiments there was a corresponding series of checks of the same variety as were treated. The remainder of the plants, not included in the experiment, were sprayed with either Lethane or Loro, following the makers' recommendation. The plots were treated August 8, 15 and 20. After this, leafhoppers ceased to be a problem in the field. The following table gives the results with various materials used.

Material	Repelling Value	Effect on Insect	Injury to Plant
Lethane 440 and spreader 1:300	Poor	Kills by Contact	No injury
Lethane dust	Fair	No kill	No injury
Loro and spreader 1:400	Poor	Kills by contact	No injury
Pyrethrum A dust	Good temporarily	Very slight	No injury
Garden Guard	Very good	Very slight	No injury
Four per cent nicotine dust	Excellent and lasting	Very slight	No injury
Garden Flit dust	Fair	Very slight	No injury

While either Lethane or Loro with spreader killed any individuals that were hit, it had little or no lasting effect and the plants were reinfested almost immediately from other sources until the insect population was reduced by natural causes.

The dusts, on the other hand, were more satisfactory than the results given on the table would indicate. All dusts used acted as repellents, few if any leafhoppers returning to the dusted plants after they had been treated. Not only were the dusted plants free from leafhoppers but they put out vigorous new growth, in some instances doubling the growth of non-dusted plants. Of the dusts used, the four per cent nicotine dust gave the most satisfactory results in that it acted as a repellent for a longer time. Since all these dusts remained active long after the various killing agents had deteriorated, it was decided that in all probability the carrier itself might be the repellent.

With this in mind, a number of especially susceptible plants stunted by leafhoppers were dusted with inert carriers commonly used in dusts. The materials selected were Disilo, an infusorial earth, talc, and flour. Each plant was dusted twice. The infestation was checked with the first application and no difference would be detected between the materials used. Also plants dusted with Disilo, talc or flour were apparently as adequately protected from leafhopper attack as plants dusted with four per cent nicotine dust, or with high grade Pyrethrum.

The only common property possessed by the dust carriers showing repellency was their whiteness. Dusts such as Lethane, Garden Guard, etc., showed color but did not repel.

E. I. McDaniel, *Michigan State College*. 1-17-36

Injury to Carrots by the Potato Scab Gnat, *Pnyxia scabiei* (Hopkins).—Early in October 1935, I received a few carrots showing evidence of some insect feeding. The injuries were quite similar to those caused to potato tubers by the larvae of certain sciarid flies, and may be characterized as rather large, deep cavities, more or less filled with refuse and larval excrement. They resembled closely the potato tuber injuries illustrated by Gui, in fig. 5 of Ohio Agr. Exp. Sta. Bul. 524, 1933. Upon careful examination, several typical

black-headed sciarid larvae were found in the injured areas, but adults were not immediately obtained from these larvae.

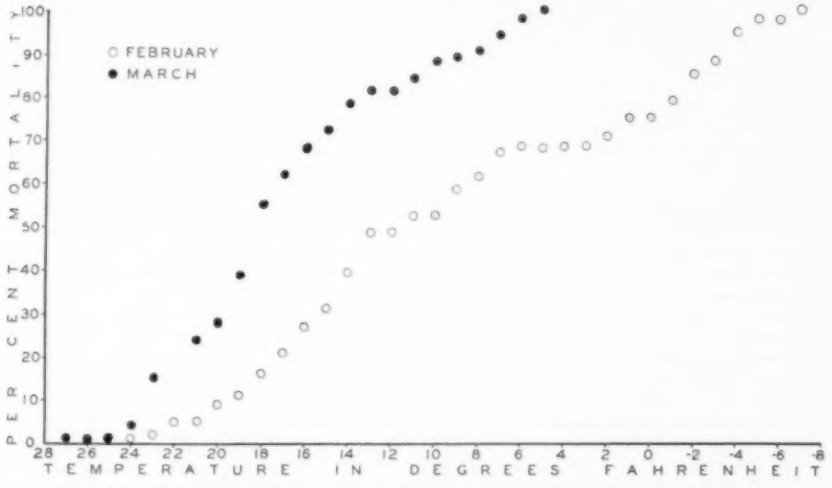
The carrots were placed in storage at a temperature of 6–8° C and left undisturbed until early in January 1936. They were brought out into room temperature on Jan. 13, and on Jan. 20 an adult female sciarid fly emerged, which was determined as *Pnyxia scabiei* (Hopkins) by Dr. O. A. Johannsen. To my knowledge, this is the first record of injury by this species on field-grown carrots.

A bacterial rot, quite typical of that caused by *Bacillus caratororus* Jones, was present and numerous typical bacteria were found in the affected tissues. Inasmuch as this pathogene enters only through wounds, it would appear that the injuries from these scab gnat larvae might be important avenues for infection by this pathogene.

These carrots were sent from material secured at Bismarck, Burleigh county, N. D., by Prof. J. A. Munro of the North Dakota experiment station.

F. Gray Butcher, *Cornell University*. 2-19-36

Freezing Temperatures of the Chinch Bug, *Blissus leucopterus* Say.—In February and March 1935, 187 chinch burgs were frozen in a chamber cooled by the evaporation of solid carbon dioxide (dry ice). The insects used were removed from hibernation and frozen the same day. Clumps of grass in which they were hibernating were taken into the



Mortality curve of adult *Blissus leucopterus* when exposed to freezing temperatures in February and March.

laboratory and the bugs removed as needed. This avoided excessive handling and the necessity of holding them in artificial conditions for any great length of time.

The cooling chamber consisted of a three-pint thermos bottle with a cork stopper through the center of which a metal tube was inserted so that it extended into the carbon dioxide. The temperatures were recorded by the thermocouple method using a self-compensating potentiometer. The thermojunction was made of number 30 copper and constantin wires. The specimen to be frozen was placed on a stick under the thermojunction, which was held in contact with it by a piece of cheesecloth and a gelatin capsule. The bug was immediately placed in the cooling chamber and undercooling and freezing temperatures determined. The time was recorded from the beginning of the fall of temperature to the rebound.

It was found that the bugs were much more resistant to cold in February than in March (See table and fig.). This indicates that this species goes into true hibernation which is broken in the early spring, at which time its resistance to cold is lowered. On about the same dates the cotton boll weevil[1] *Anthonomus grandis* Boh. had a mean freezing point of

[1] **Sooter, C. A.** The freezing and undercooling temperature of the boll weevil. Unpublished thesis, Oklahoma A. & M. College.

10° F for February and 15° F for March. It was therefore only slightly less resistant to cold than the chinch bug in February, but more so in March. The boll weevil emerges from

Resistance of chinch bugs to cold, Stillwater, Okla., 1935.

Date Insects Collected and Frozen	No. of Bugs Used	Temperature in Degrees Fahrenheit								
		Undercooling point			Freezing point			Rebound		
		max.	*min.*	*mean*	*max.*	*min.*	*mean*	*max.*	*min.*	*mean*
Feb. 5	90	22	−12	5.2	24	−7.2	9	9	1	4.02
March 5–6	97	23	−1.7	14.4	27	5	17.5	7.7	1	3.90

hibernation in Oklahoma in June and the chinch bug in April, which may account for the shift in resistance. The number of degrees of rebound was greater for chinch bugs in February than March although their undercooling and freezing points were significantly lower at the same time. This indicates that there is not a direct correlation between winter hardiness of the chinch bug and the amount of bound water present in its tissues.

Ephraim Hixon and C. A. Sooter, *Oklahoma A. & M. College, Department of Entomology.*
1-17-36

Lead Arsenate and Wetting Agents for Corn Earworm Control.—For several years the writer has attempted to find a satisfactory wetting agent which would carry a stomach poison deeply into the bundle of corn silks. No other means of control for the larvae of the corn earworm has given any promise of success in heavily infested regions. The silks grow so rapidly that a few larvae can usually enter the bundle of silks without ingesting a fatal dose of poison when the poison is deposited on the exposed silks only. Wetting agents previously used had been unsatisfactory due to failure to penetrate, injury to the ear or by imparting an undesirable flavor. During the past summer several new wetting agents at .25 per cent were combined with lead arsenate at .5 per cent. After three to four applications at four-day intervals the percentages of infestation were as follows: sodium oleyl sulfate 5.8 per cent, SS-3 5 per cent, lethane spreader 2.3 per cent, sodium lauryl sulfate 2 per cent, tergitol-7 6 per cent, lead arsenate alone as a dust 61 per cent, checks comparable to the first three 70 per cent, checks comparable to the last three 75 per cent.

The penetration by the liquids was much greater than expected and severe injury to many ears resulted. The injury was due largely to the lead arsenate, for where it was omitted little injury resulted. In a second series of experiments applied during August, when earworm infestation was at a maximum, the concentration of both ingredients was reduced one half. Little injury resulted and the control of earworms was better than any previously attained under similar conditions. No unusual flavor could be detected in any of the treated ears. With four applications at four-day intervals the percentages of ininfestation were as follows: SS-3 34 per cent, sodium oleyl sulfate 17 per cent, lethane spreader 59 per cent, tergitol-7 54 per cent, sodium lauryl sulfate 58 per cent, lead arsenate alone (dust) 82 per cent, check 99 per cent.

The liquids were applied with a specially prepared nozzle delivering a fine straight jet which was directed onto the silks from above for about 1 second. Ears were harvested at the roasting-ear stage regardless of the number of applications they had received. The percentage infestation given includes all ears with living worms on the cob or in the silks and those in which worms had fed on the cob and left. Ears with dead worms only were counted as uninfested. With both series one plot was dusted with lead arsenate on the same days for comparison. Lethane spreader was supplied by Röhm & Haas Co., tergitol-7 by Carbide & Carbon Chemicals Corp., and the others by Grasselli Chemical Co.

Corn varieties most resistant to earworm injury, that is varieties with long husks, should be best adapted to this treatment since they would have longer silk bundles within the husk for retaining the poison. Further work on the number and timing of applications, type of nozzle and the concentration of materials will be necessary before it can be determined whether a practical control can be worked out along these lines.

B. B. Fulton, *North Carolina Agricultural Experiment Station.*
1-17-36

Selenium in Dormant Sprays.[1]—In the course of compounding and testing a variety of dormant spray formulae for the control of the cherry case-bearer in northeastern Wisconsin in 1935, a potassium-ammonium-seleno-sulfide compound (Selocide concentrate) gave some rather unexpected results. It was tested in combination with both dormant

[1] Published with the permission of the director of the Wisconsin Agricultural Experiment Station.

strength lime sulfur and a tank-mixed emulsion of a light lubricating oil. This product is on the market as a red spider control measure and is recommended at 1–600 in combination with either summer strength lime sulfur or a summer oil. It is not sold as a general contact insecticide for the control of aphids, leafhoppers, etc.; and has not been tested elsewhere in dormant treatments so far as known.

The Selocide concentrate was used with both oil and lime sulfur at rates of 1–400 and 1–200 in the final dilutions. The combinations with oil were in a series consisting of a single oil (Diamond paraffin) which was stepped up in toxicity with various oil-compatible contact insecticides. These combinations were tested at a low concentration (4 per cent instead of the usual 6 per cent) in order to reveal the merits of the respective supplementary materials included. Thus the final emulsions contained the complete experimental formulae at a concentration of 4 per cent, rather than 4 per cent straight oil plus the supplementary materials. Calcium caseinate (Kayso) was used at 1–100 as the emulsifying agent in all cases. It should be stated at this point that Selocide concentrate is non-miscible in Diamond paraffin.

Counts were made to determine the resultant controls of the cherry case-bearer *Coleophora pruniella* Clem., the bud moth *Spilonota ocellana* Denis & Schiffermüller, and the fruit-tree leaf roller *Archips argyrosphila* Walker. The results are shown in the following table.

Formula	Rate	*Per cent Kill* Case-Bearer	Bud Moth	Leaf Roller
Diamond Paraffin (check)	4%	71.6	48.5	81.4
Diamond paraffin plus 6¼% Selocide concentrate	4%	90	77.3	93.8
Diamond paraffin plus 12½% Selocide concentrate	4%	97.8	78.8	85

In the parallel series of experimental formulae in which lime sulfur was used as the basic material instead of oil, a low concentration of the base was also used (one gallon of liquid lime sulfur to eleven gallons of water), but here the actual quantity of lime sulfur was the same in all plots, so that all supplementary materials used increased the total volume of concentrated insecticide in the final preparations. Here it was found that 1-12 lime sulfur plus Selocide concentrate at 1–400 and 1–200 gave case-bearer kills of 99.5 per cent and 99.9 per cent respectively. As a basis of comparison, the same concentration of lime sulfur plus Black Leaf 40 at 1–600 gave 99 per cent control, and a fourth plot of 1-12 lime sulfur without a supplement gave 88.3 per cent kill. The Selocide concentrate—lime sulfur combinations were apparently not effective in leaf roller control, and only partially effective against the bud moth.

It is true that the concentrations of Selocide concentrate used were rather high but this was logical in preliminary trials. It is also possible that the improved toxicity of the oil preparations was due to some ingredient other than selenium (possibly through an effect upon the physical properties of the emulsion) rather than to the toxicity of selenium itself. On the other hand, these applications were all made from the ground (as is recommended for case-bearer control), while leaf roller eggs and bud moth larvae are more effectively sprayed from above. It must be remembered that these results are based on a single season's work and therefore need substantiation.

John H. Lilly, *University of Wisconsin.* 1-17-36

Thiuram Sulfides as Repellents to Leaf-feeding Insects.—In laboratory tests with organic compounds it has been found that the thiuram sulfides repel several leaf-feeding insects. They apparently prefer to die of starvation rather than to feed upon foliage coated with a thiuram sulfide spray. Investigations with these compounds have been continued since July 1933, when they were suggested by Dr. W. H. Tisdale of the Grasselli Chemical Co., who in 1931 had noted the repellent affect of tetra methyl thiuram monosulfide to the eastern tent caterpillar. The following insects have been prevented from feeding upon their host plants by thiuram sulfides in dusts and sprays: Colorado potato beetle (potato), Mexican bean beetle (bean), eastern tent caterpillar (wild cherry), and Japanese beetle (smartweed). The most effective compound in this group discovered to date is tetra methyl thiuram disulfide.

H. G. Guy, *Delaware Agricultural Experiment Station.* 1-17-36

Remarkable Phenomenon of Reproduction in the Parasitic Hymenoptera.—A thorough knowledge of the biology of a parasite may not be essential for its successful use in reducing the average population density of a destructive host species. Lack of such knowledge, however, precludes the use of many species of parasites and thus limits the field of successful biological control.

Recently, while working out the life histories of several species of the genus *Coccophagus*, the writer noted a remarkable reproductive phenomenon characterized by a differential development of the sexes.

As in many other hymenoptera the progeny of unmated females are always males. In the case of each species of *Coccophagus* investigated, the male sex was produced only hyperparasitically on individuals of its own or other parasitic species. Mated females produced only females and these developed only as primary parasites of lecaniine scales and mealybugs. Thus we have species in which the males develop only as parasites of a hymenopterous larva and the females only as parasites of a homopterous nymph or adult. This marked differentiation in the host relations of the male and female larvae is apparently unique. P. H. Timberlake reported in volume 6 of the JOURNAL the occurrence of such a differentiation in the host relations of *Coccophagus lycimnia*, but he did not consider it to be a habit essential to the existence of the species.

Reproduction in a pure culture of an aphelinid species having this habit involves the destruction of the female larvae by the male larvae. The methods by which this is accomplished vary in different species.

In certain species such as *C. scutellaris*, *C. modestus* and *C. lycimnia* the stimulus of fertilization is followed by a marked change in the host preferences of the females. *C. scutellaris* and *C. modestus*, when mated, normally oviposit in the body cavity of lecanium scales. Before mating they normally deposit their eggs in the body fluids of an immature primary parasite. Both sexes are endoparasitic. *C. lycimnia*, when mated, likewise oviposite in the body cavity of lecanium scales, but when unmated it oviposits only in parasitized scales. the contents of which have been consumed by the primary inhabitant. The eggs are deposited on the surface of the primary parasite which is then in the last larval instar. In this case only the females are endoparasitic. The males develop ectoparasitically, and the early larval instars differ from those of the female in the structure of the respiratory system and in other morphological characteristics.

In other species, as in *C. gurneyi*, fertilization is not followed by any change in the oviposition behavior of the females. Both male and female eggs are deposited in the body cavity of the homopterous host. If the male egg is deposited first the embryo completes its development, but hatching is inhibited as long as it is exposed to the body fluids of the host. This male egg does hatch, however, if subsequently the contents of the host are consumed by another parasitic larva and the body fluid of the homopterous host has been replaced by air. The male larva, so produced, is a heavily chitinized planidium with ambulatory spines. When it emerges from the egg the larva locates the primary inhabitant, penetrates the body wall, and develops endoparasitically until nearly full grown, then bores its way out and completes its development as an ectoparasite.

In pure cultures of most species uneven broods are essential for continuous reproduction. Field liberations should consist of mated and unmated females in order to facilitate establishment of the species.

S. E. FLANDERS, *Riverside, Calif.* 3-5-36

Early Work with Fixed Nicotine.—I note that some of the bibliographies of fixed nicotine have failed to record the work done by Professor A. F. Conradi when he was with the South Carolina experiment station. This is because no records were ever prepared for publications that had nation-wide distribution. It is interesting to note his work from the historical standpoint. In the early 1920's, Professor Conradi used 5 per cent of nicotine sulfate combined with diatomaceous earth in tests designed to control the boll weevil *Anthonomus grandis* Boh. on cotton. The finely ground diatomaceous earth was very light. Some of the dusts were kept in storage several years with no loss of nicotine that could be determined by chemical tests. Results of this work have been called "promising." In his last experiments, 6 per cent of nicotine sulfate was combined with rose tripoli from Missouri and used as a dust in plot tests for boll weevil control at the South Carolina substation at Florence, S. C. The results are reported on pages 50–54 of South Carolina Experiment Station Bulletin 223, June 1925. By use of this nicotine dust, gains of from $3 to nearly $4 per acre were demonstrated.

In addition to calling attention to the publication, I wanted to record the formula used in making the nicotine-tripoli dust for the benefit of research workers, as the bulletin does not contain it. I was associated with Professor Conradi at the time this work was in progress and know that the formula was omitted accidentally.

C. O EDDY, *Louisiana Agricultural Experiment Station.* 1-17-36

European Sawfly *Pristiphora geniculata* Attacks Mountain Ash in the United States.—In July 1928 two collections of sawfly larvae taken on mountain ash in Shelburne and North Adams, Mass., were sent to the Melrose Highlands, Mass., laboratory of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, with reports that they were abundant and were defoliating the trees.

Each year since 1928 reports or collections of larvae have been received from widely scattered localities in New England and New York—from Bar Harbor in Maine, throughout the White Mountain section of New Hampshire, from Stowe and Castleton, Vt., from several localities in both eastern and western Massachusetts, and from as far west as Delhi, N. Y.

Adults reared from the North Adams, Mass. collection, issuing in May 1929, together with adults from the Delhi, N. Y. collection, issuing in May and June 1930, were tentatively named as *Pristiphora*, near *banksi* Marlatt, in October 1930. In December 1935 Dr. H. H. Ross, of the Illinois State Natural History Survey, Urbana, Ill., identified these specimens as the European species *Pristiphora geniculata* Hartig.

In several localities, particularly where mountain ash is valued as a shade tree, it has been necessary to practice artificial control. At the Acadia National Park in the summer of 1935, local control was applied along many miles of roads by pruning and burning the twigs covered with early-instar larvae. A lead arsenate spray, such as is used successfully for other leaf-eating shade tree insects, will control this pest.

Laboratory records indicate that the majority of the adult sawflies issue during the latter half of May and early in June, but in 1930, and again in 1932, a few adults issued in August of the same year the larvae were collected, thus indicating the possibility of a partial second generation.

J. V. SCHAFFNER JR., *U.S.D.A., Bureau of Entomology and Plant Quarantine.* 2-28-36

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JOURNAL OF ECONOMIC ENTOMOLOGY

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SPECIAL MEETING OF THE EXECUTIVE COMMITTEE

A PRECEDENT for the Association was established when a meeting of the Executive Committee was held in New York on February tenth, last. According to one of the members of the committee who has been directly connected with the Association since its inception, this is the first time that this committee has met between the annual meetings since it was organized. A full day was devoted to the meeting, which convened early in the morning and did not adjourn until late evening. With the exception of two, all members of the committee were present.

Members of the Association who have not attended a business session or who have failed to read the report of the annual meeting, may not realize to what an extent our organization has grown or the amount of work that involves upon the Secretary of the Association and the Editor and Business Manager of the JOURNAL. The report of the Secretary presented at the St. Louis meetings shows that the Association had at the close of 1935 a total membership of 1150, and at the same meeting the Membership Committee reported a net gain of 57 members, making a total membership of 1207 at the present time. The Secretary also reported that the total receipts during 1935 were $15,847.28 and the expenditure was $8,332.41, representing a turnover of over $24,000 during the year! In addition, the permanent fund amounts to nearly $17,000 and the cash on hand about $7,500. Such being the case, it can readily be understood that administration of the affairs of the Association in a businesslike and efficient manner entails not only a great deal of work but much care and thought.

Among the more important matters considered at the meeting were revision of the Constitution—it may interest members to know that although Sections and Branches of the Association have been formed from time to time no provision for such organization exists under the present Constitution; the question of dealing with back numbers of the JOURNAL which have accumulated since publication of the first issue; the establishment of policies with regard to the JOURNAL; the providing of sufficient clerical and stenographic assistance to the Association officers; the handling of finances; and numerous details in connection with the Association's affairs.

One of the ideas behind the movement to establish a "Permanent Fund" was to the effect that when the said fund had grown to sufficient size, consideration should be given to the appointment of a Permanent Secretary to administer the affairs of the Association. Should we con-

tinue to grow as rapidly in the future as in the past, it may not be many years before this problem will have to be faced.

As a result of this meeting it was realized by all those present that the former policy of holding a single meeting of the Executive Committee each year, *i.e.*, at the time of the annual meeting, did not provide sufficient time to go into the business and other activities which are increasing and broadening from year to year. Consequently, if the need arises another meeting of the Executive Committee may be held before the annual meeting.

LEONARD S. MCLAINE

Obituary

Andrew Nelson Caudell 1872–1936

Andrew Nelson Caudell was born at Indianapolis, August 18, 1872, and died at Washington, D.C., March 1, 1936. Early in the life of the deceased his parents moved to Oklahoma. Here he grew to manhood, spending much of his time working on the farm. He attended the Oklahoma Agricultural and Mechanical College, from which institution he was graduated in 1897. Even before graduation he served as an assistant in entomology in the college of his choice, and following graduation took up work in connection with the gypsy moth at the Massachusetts Agricultural College, Amherst. In 1898 Caudell joined the Bureau of Entomology, U. S. Department of agriculture, and became custodian of the Orthoptera in the U. S. National Museum, both of which positions he held until his death.

Andrew Nelson Caudell

As an entomologist Caudell's work on the orthoptera, his indexing work on the lepidoptera, his contributions to taxonomic nomenclature and his work on some of the more generalized smaller orders of insects were outstanding. As a man his genial personality, his loyalty, his integrity and his willingness to help others made him many friends. He knew no enemies, was without petty vices, and was ideally devoted and happy in his family life.

The deceased had but few hobbies. However, one of them, stamp collecting, he followed with the greatest of enthusiasm. He was particularly interested in United States stamps, and of late years made many purchases of uncanceled new issues.

Caudell early attained a reputation for his knowledge of the rules of taxonomic nomenclature, and became in 1912 the joint author with Nathan Banks of "The Entomological Code." This code embodied largely the results of the best taxonomic practices of the entomologists of that time and supplemented the earlier "International Code of Zoological Nomenclature." This it did particularly in one respect, *i.e.*, it covered certain phases of taxonomic practice that were not covered by the international code. It should also be noted that this code by Banks & Caudell was provided with a much needed index, thus eliminating a handicap that long existed for the zoological code.

While almost of the "old school" of entomologists, being a contemporary of Dyar, Banks and Schwarz, Caudell was keenly alert to the newer developments in fields of his interest. This was no better shown than in his more recent work on Silvestri's new order of insects, the Zoraptera, and upon that peculiar group of orthopteroids known as the Grylloblattidae.

During the latter years of his life much of his time was devoted to two major projects (1) the completion of a catalog of the North American orthopterous insects for the period subsequent to 1900, up to and including the year 1925, and (2) the preparation jointly with H. A. Allard of the Bureau of Plant Industry, of a manual of the Orthoptera of Maryland, Virginia and the District of Columbia. The first of these projects was completed, and the manuscript now awaits only funds for publication. It comprises over a thousand typewritten pages, and in it are given locality records, synonymy and a very long bibliography. The second project was nearing completion at the time of his death, and Mr. Allard informs the writer that it will be completed for publication.

The deceased is survived by a wife, Penelope Lee Cundiff Caudell; a sister, Mrs. Allie Cripe; a daughter, Mrs. Easter Shade; and a granddaughter, Sylvia Marie Shade. He lives on in our memories as a most cherished friend and as an inspiration to all who had made his acquaintance. But few, if any, of Caudell's many associates can feel his loss as keenly as the writer. For years we had worked in adjoining rooms at the National Museum, and in all those years not a single incident had arisen to mar in the least our most happy confidence in and friendship for each other. His place cannot be filled.

H. E. EWING. 3-26-36

Review

Report of the East Africa Subcommittee of the Tsetse Fly Committee, Economic Advisory Council. London, 1935. 56 pp., 35 cents.

This is very comprehensive, admirably written and up-to-date account of the present status of, and recommended research upon, sleeping sickness of man and nagana or tsetse fly disease of animals. Together these diseases constitute one of the most complex and intricate problems in the entire field of entomology or of medicine and in the opinion of the committee hold the key to future prosperity of East African territories. The report of 56 pages outlines three general methods of control: (a) administrative methods, especially by the concentration of native populations; (b) the control of tsetse flies, especially by the proper use of grass fires, and, on the other hand, the densification of the vegetation by preventing grass fires; and (c) chemotherapy, especially the use of germanin (Bayer 205) or Fourneau 309 and tryparsamide, for sleeping sickness, and antimosan for nagana.

A few of the intricacies and complexities of the problem are suggested by the fact that certain effective controls disastrously influence the water supply and promote erosion; that there are no known morphological characters for distinguishing the three most important species of trypanosomes; that there is evidence of a tendency for the trypanosomes to acquire powers of resistance to drugs to which they have been subjected for some time; and that among tribes where cattle are the basis of wealth and social custom, losses through nagana may lead to moral degeneration as well as impoverishment.

The committee's report includes deep recognition of the work of specialist entomologists and concludes with strong recommendations for the continuation of research along comprehensive and widely cooperative lines.

C. L. METCALF. 3-11-36

Horticultural Inspection Note

THE ANNUAL CONFERENCE of state leaders in charge of white pine blister rust control in the lake states was held in Milwaukee, Wis., March 16 to 18 inclusive. Dr. S. B. Fracker, principal plant quarantine administrator in charge of this project for the Bureau of Entomology and Plant Quarantine, and his assistant Dr. James F. Martin represented the Washington office. H. N. Putnam, in charge of the lake states region, acted as chairman. R. A. Sheals and J. M. Corliss, representatives of the Division of Domestic Quarantines of the Bureau outlined the new regulations proposed for establishing sanitation zones around nurseries growing white pine. Warren V. Benedict, in charge of blister rust control work in California and Oregon, outlined the problems in that area. State leaders and their assistants were present from seven of the lake states.

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ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS

The thirteenth annual Rocky Mountain Conference of Entomologists will be held in the University of Wyoming summer camp, Centennial, Wyoming, August 16 to 21 inclusive. The University camp is ideally located in the Medicine Bow mountains, 40 miles west of Laramie, Wyoming, and 100 miles north and west of Fort Collins, Colorado, at an altitude of 9500 feet.

The Medicine Bow mountains are noted for their rugged scenery and good trout fishing.

The University camp consists of a large central lodge divided into a recreation hall, kitchen, and dining hall. All meals will be served here. Sleeping quarters are separate cabins equipped with stove, beds, mattresses and blankets. Each cabin accommodates three. Details are not fully worked out as yet but it is thought board and lodging will not exceed $2 per day.

The change in meeting place from Pingree Park, Colorado, where the twelve previous conferences have been held, should be noted.

Anyone interested in the meetings should get in touch with the secretary for later details. Reservations must be made in advance.

Geo. M. List, *Secretary*
Colorado State College
Fort Collins, Colorado